

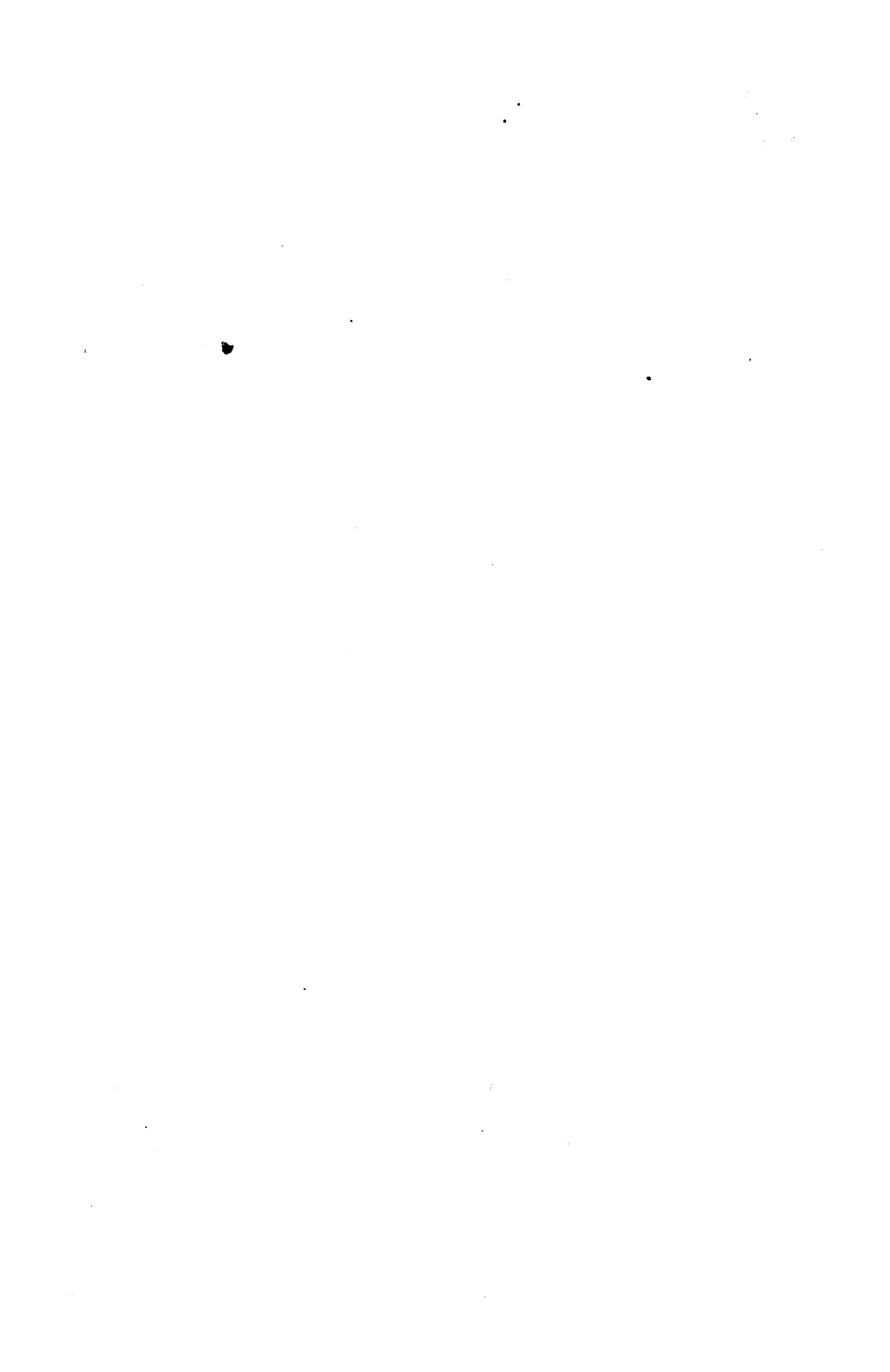


AGRICULTURAL RESEARCH INSTITUTE

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# PLANTERS' RECORD

VOL. XLII

A quarterly paper devoted to the sugar interests of Hawaii,  
and issued by the Experiment Station for circulation among  
the plantations of the Hawaiian Sugar Planters' Association.

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# THE HAWAIIAN PLANTERS' RECORD

VOL. XLII

H. L. LYON, *Editor*

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ORGAN OF THE EXPERIMENT STATION OF THE  
HAWAIIAN SUGAR PLANTERS' ASSOCIATION

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1938

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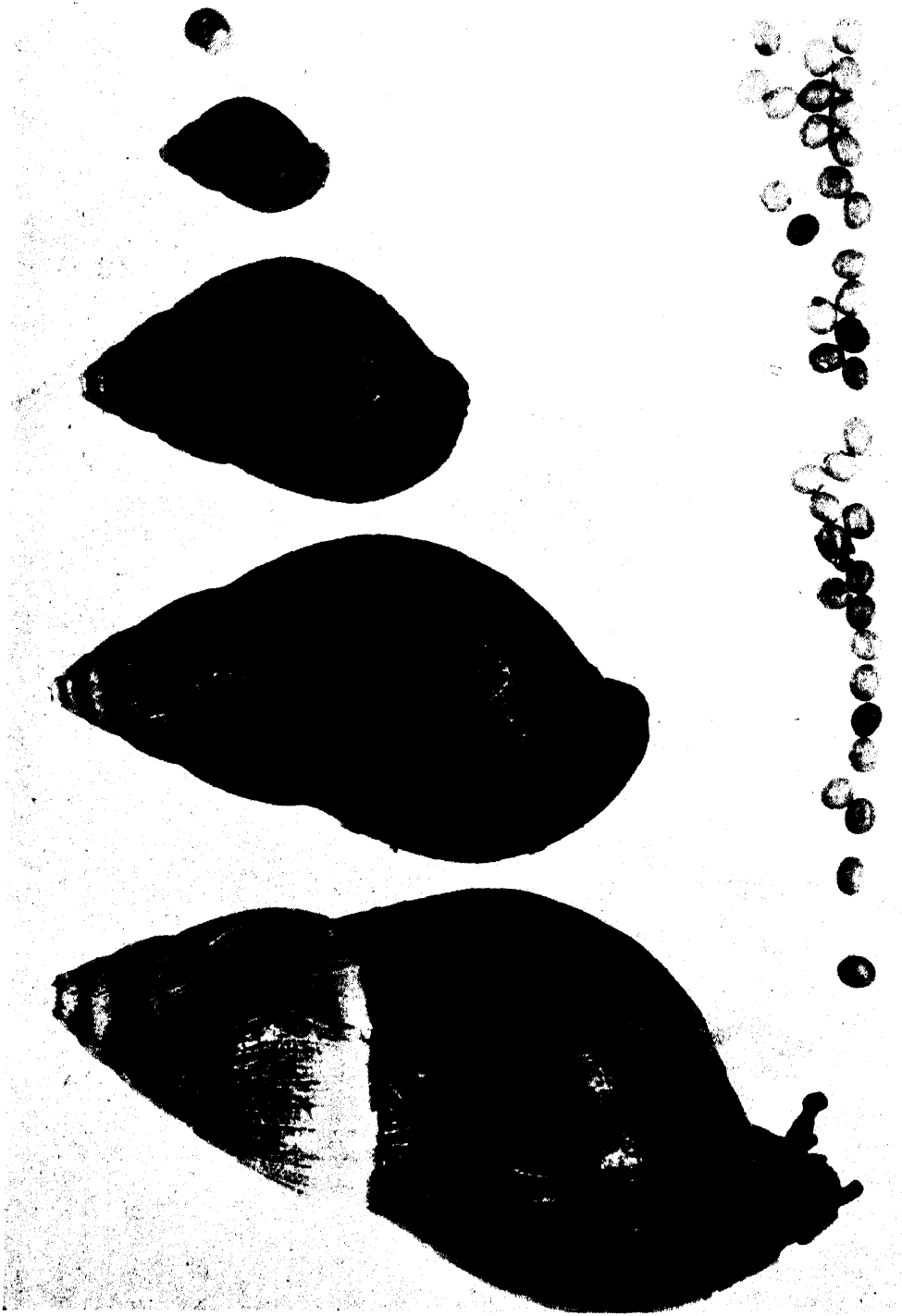
FIRST QUARTER



Rat feeding station No. 145 being prebaited with unpoisoned oats prior to final baiting with thallium-treated rolled oats.

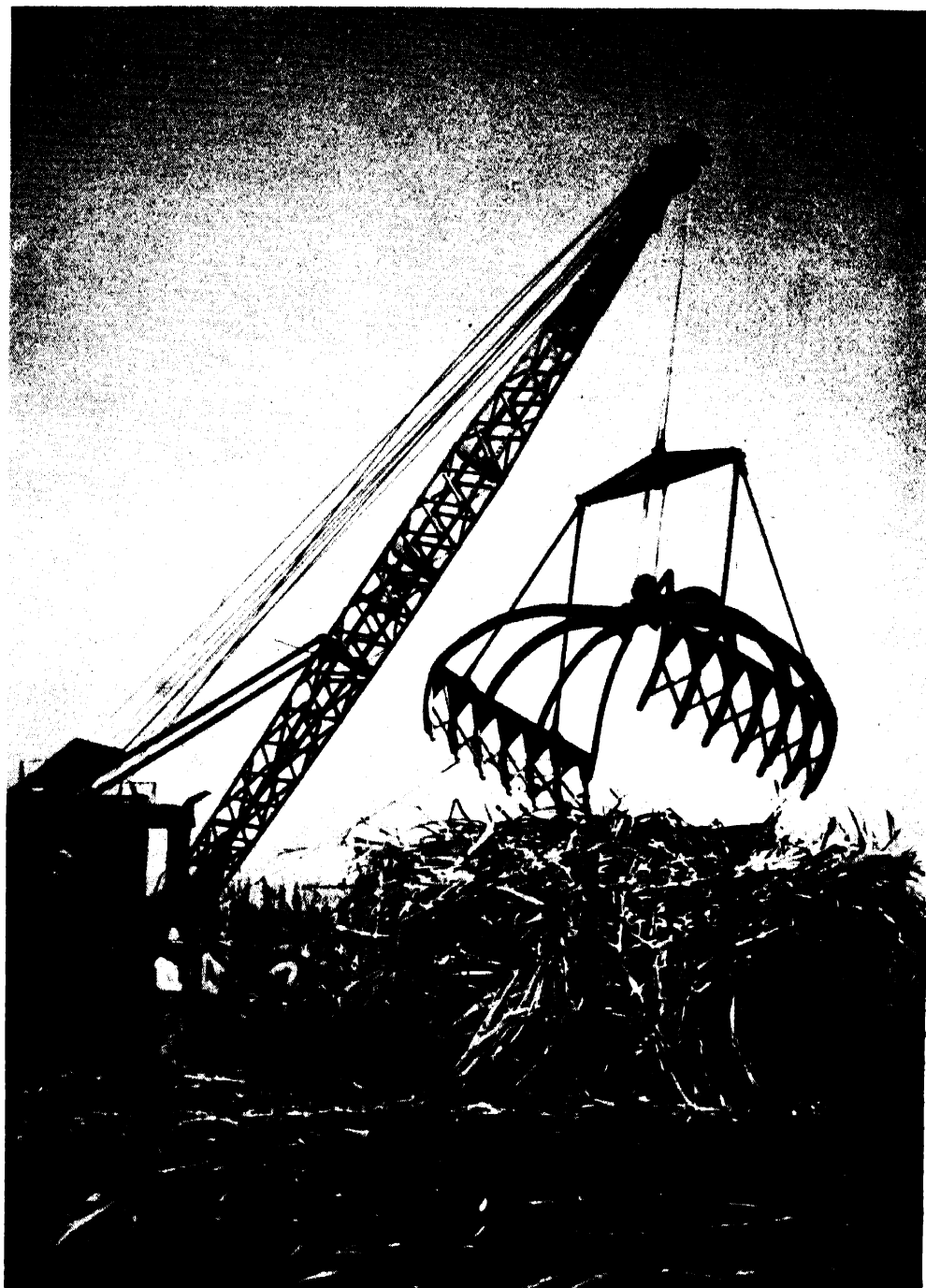


SECOND QUARTER



Giant African Snail—Young and adult in natural size—eggs slightly enlarged.

## THIRD QUARTER



GRAB HARVESTER

## FOURTH QUARTER



Cane gardens filled with many varieties of *S. officinarum* are found near all the villages on the Ramu plateau of New Guinea (elevation 5500 feet). Photo by C. E. Pemberton.





# THE HAWAIIAN PLANTERS' RECORD

Vol. XLII

FIRST QUARTER 1938

No. 1

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*A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.*

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## Upendra Kumar Das

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It is with deepest regret that we record the accidental death of Dr. Upendra Kumar Das in his biochemical laboratory on October 22, 1937. Without doubt the part he was taking in research connected with problems of the sugar industry was an outstanding one, and it will be difficult and perhaps impossible to find another scientist motivated by the same practical viewpoint which he held.

As a student after coming to Hawaii in 1924, his record was one of which to be proud. At the University of Hawaii he completed the work for his Bachelor's degree in three years and was graduated in 1927 with honors, and this was done while he was earning his own way, and also finding time to join and eventually lead the University soccer team. After graduation, although then employed, he continued his studies in the biological chemistry laboratory and received his Master's degree in 1930. Later securing a leave of absence from his work, he spent a year in residence at the University of Minnesota and was granted his Doctor's degree there in 1935. His election to the national honor society, Sigma Xi at Minnesota, bespeaks the record he made there.

The life of Dr. Das was intimately connected with the Experiment Station. While still a student, he was employed as a part-time student assistant and upon his graduation in 1927 he was appointed an assistant agriculturist. Thus he learned to know sugar cane as it grew in the field under many and varied conditions. This experience contributed to all of his work thereafter, and gained for him the respectful attention of the fieldmen in whose problems he became interested.

His contributions to sugar cane agriculture were conspicuous. His discovery and perfection of the method of preserving cut cane stalks with their tassels has been largely responsible for the success of the crossing technique that is now used by our cane breeders. His collection of sugar cane crosses made in India in 1929 added another lot of breeding material to our collection. His studies of weather records laid the foundation for a simple measurement of effective temperature and added much to our understanding of temperature-yield relationships. Recently his work on the nature and progress of sugar storage in the cane plant, and particularly the key role played by nitrogen fertilization in connection with cane quality has given us new facts and a new understanding of cane ripening. Still more recently, his in-

vestigation of the possible values in some sugar mill by-products has attracted a respectful attention.

Dr. Das was a generous contributor to *The Hawaiian Planters' Record*, and was ever willing to share his keenly analytical point of view with his associates. He will be remembered for his constructive suggestions, and for his optimism, his happy nature, and his personal kindness.

R. J. B.

### **In This Issue:**

#### *Chemical Weed Control:*

The purpose of this article is to bring into small compass data and discussions based upon experiences and recommendations of specialists throughout the world who have developed chemical means for combating the growth of weeds.

Advantages and disadvantages of various chemicals, when used for specific herbicidal purposes, are enumerated. Hazards, precautions and safety measures, which may be of aid to the worker engaged in chemical weeding pursuits, are cited.

#### *The Prebaited Feeding-Station Method of Rat Control:*

The rat is acknowledged to be a real economic as well as a health menace in many sugar cane areas. A plan of rat control by prebaiting in field areas with unpoisoned bait followed by poisoned grain is described in detail. The materials and equipment are described and illustrated, and the best baits and attractants with the concentrations of poison are discussed. The results of a series of experiments that have been carried on at intervals since 1935 are given with tables and illustrations.

#### *Utilization of Molasses:*

The results of a beef cattle fattening experiment, using a ration of which 83 per cent was local by-products, are presented. This experiment was run in cooperation with the Hamakua Mill Company, Hawaii, using steers from Kukaiau Ranch. The rations included molasses, bagasse, pineapple bran, and cane tops, with soybean oil meal for the protein component.

The chief purpose of this experiment was to test the pen-fattening (dry-lot) method under our conditions, and to compare the quality of beef produced with that produced by similar animals on excellent pasture. The most important results were in the quality of the carcasses. In the pasture-fed group 20 per cent of the carcasses were rated "good," and in the pen-fed groups 50 per cent were "good." The amount of marbling of the meat was greater and its flavor much better in the pen-fed carcasses, indicating an improvement in market quality which would bring an increased price in an established and discriminating market.

A long-time feeding experiment with a ration including 55 per cent of sifted bagasse gave results indicating that its feeding value is considerable. The experimental animals were rabbits, which were exercised in a machine and fed on this bagasse ration over a period of two-thirds of the normal life span of the rabbit.

A growth experiment with kiawe bean meal, which is or may be used in many areas of the Territory as a constituent of by-product rations, indicates that its proteins are of fairly good quality, and that 30 per cent of the meal in a ration gives excellent results.

# Chemical Weed Control

By FRANCIS E. HANCE

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## INTRODUCTION

Ball, Madson and Robbins (12) observe that less effort and expense have been expended upon the elimination of weeds than to the reduction of the ravages of insect and fungus diseases and that in spite of this fact that weeds cause more loss to agriculture than do insects and fungi combined. They state:

Few people, probably, ever realize what a burden weeds add to human existence. The production of almost all crops largely consists of a battle with weeds. The preparation of many products of the soil for human consumption involves the elimination of weeds or their effects. Weeds may cause illness or even death in men or animals. They militate against our full enjoyment of the outdoors; they are the bane of every home owner and amateur gardener. Few human activities, in fact, are not affected in some measure by weeds—pests which increase the cost of our food and clothes, hamper our movement, menace our health, and dampen many of our pleasures.

Weeds have been said to levy, in one way or another, an annual tax on agriculture and industry in the United States of about three billion dollars. No estimate has been made of the weed tax in California, but it may be safely assumed to be at least proportional to the country as a whole, or a minimum of sixty million dollars, the larger portion of which falls on agriculture. Indiana estimated in 1920 that its average annual loss through weeds was \$210 per farm; Wisconsin's estimate in 1927 was about \$244 per farm.

Weeds cause losses in many ways, the more important of which are as follows:

1. They offer serious competition to crops for plant food, moisture and light.
2. They add to the cost of crop production because of the large amount of labor necessary to keep them in check.
3. They increase the cost of preparing many crop products for consumption.
4. They impair the quality and destroy or reduce the value of many products of the soil.
5. They harbor insects and fungus pests destructive or injurious to economic plants.
6. They are sometimes poisonous and may endanger the health or life of men and animals.

A review will now be presented citing, without needless repetition, typical examples of chemical weeding practices as reported by workers throughout the world. Descriptions and classifications will be made of the chemicals employed, their proven effectiveness, their hazardous nature, if any, and their toxic effects, if reported, on desirable vegetation, on soils and on animals and humans.

## SODIUM AND OTHER CHLORATES

(Quotation: In bags, powdered, \$0.065 to \$0.10 per pound, f.o.b. New York)

Chlorates are non-poisonous after partial or complete decomposition. They are effective herbicides for certain types of weeds. Their disadvantages include various degrees of induced soil sterilization and the fire hazard which accompanies their use, particularly their careless use.

Sodium chlorate ( $\text{NaClO}_3$ ) is used more extensively than any other single chlorate compound. It is slightly hygroscopic and readily soluble in water. One drop of a solution of phosphorus in carbon disulphide placed on a crystal of sodium chlorate explodes with violence when the carbon disulphide evaporates in the course of a few seconds.

A crystal of sodium chlorate, if rubbed on the side of a box of safety matches, will emit sparks. Serious accidents are on record which have occurred with persons carrying tablets of chlorate of potash (throat remedy) in a pocket with a box of safety matches.

Chlorates decompose when brought in contact with weeds and other organic matter. The decomposition liberates free or nascent oxygen, the latter supposedly

destroying the weed tissues. It is commonly believed that in destroying weeds a chlorate liberates all of its oxygen, leaving a residue of table salt (NaCl). This belief has not been established as fact. Undoubtedly residues of undecomposed chlorates persist for some time. This assumption is supported by the ease with which chlorate-treated weeds may be kindled when dry and to the rapidity and severity of the fire which follows.

Chlorates are constituents of certain pyrotechnic mixtures used in fireworks displays. Chlorates should be used with a full understanding of their dangerous properties. Specific suggestions are made for handling this type of chemical under "The Fire Hazards of Chlorates" and "Aftereffects of Chlorates on Crops, Soils, Humans and Animals."

### *Applications of Chlorates:*

Wakabayashi (114) reports a satisfactory weed control using a few pounds to 200 pounds per acre of a chlorate as a spray solution, depending upon thickness of the weed carpet. He found the treatment most efficient when 2 months of good weather followed its application.

Bickmore (17) states that chlorates are not economical on arable land, but that the practical sphere of their usefulness is confined to highways, railways, tennis courts, paths, etc. When used on arable lands, however, he suggests that the application of from 200 to 600 pounds per acre dry chlorates be broadcast, depending on character of weeds and soil. To destroy ragwort (*Senecio sp.*)\* and soft-leaved weeds in pastures, without doing damage to grass, he recommends the use of a 2½ to 3 per cent sodium chlorate spray solution, one gallon to 15 square yards. In heavy wet soil he advocates a dry mixture of 12 pounds of sodium chlorate and 100 pounds of sand or limestone. Four to 5 pounds of the mixture are applied to 10 square yards. For paths and courts he found a 10 per cent solution effective; ½ gallon per 10 square yards. He states further that the amount of water used to dissolve the chlorate is not important, provided there is sufficient solution used to insure good distribution. He has also found it to be of no advantage to employ concentrations greater than one pound of sodium chlorate to one gallon of water.

Walker (115) reports an effective control of Johnson grass (*Sorghum halepense*), using a spraying solution prepared from 20 pounds of sodium chlorate in 50 gallons of water. The rate of application varies with severity of infestation, the average being 5 gallons of solution per 50 square feet. The above-ground portions of the grass are sprayed while the soil at the bases of the plants is fairly well soaked with the chlorate solution. In general, two or three chlorate treatments are necessary for a complete kill, applications being made at 2- or 3-week intervals. More satisfactory results are obtained by spraying on dull days as contrasted with applications made during sunny weather.

Grau (43) uses a stronger chlorate solution than either Walker or Bickmore. He states that one pound of sodium chlorate in a gallon of water is very effective in controlling Canada thistle (*Cirsium arvense*), sow thistle (*Sonchus oleraceus*), pep-

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\* The botanical terminology used in this paper has been contributed or has been checked by E. L. Caum, Associate Botanist, this Experiment Station.

per grass (*Lepidium virginicum*), bindweed (*Convolvulus arvenses*), Johnson grass (*Sorghum halepense*), Bermuda grass (*Cynodon dactylon*) and quack grass (*Agropyron repens*). Two applications are made, one in the spring after vegetative growth is well established, and a final treatment in the autumn.

Woodman (119) recommends the use of "spreaders" in 5 to 15 per cent solutions of sodium chlorate as generally effective with most weeds. He states further that the broadcasting of (dry) sodium chlorate, 200 pounds per acre, in the autumn, cleared very weedy land of couch grass (*Agropyron repens*), crowfoot (*Ranunculus sp.*) and shallow-rooted perennials. Deeply rooted weeds were not affected.

Kiesselbach, et al (66) have found liquid spray or dry applications of sodium chlorate very effective against bindweed (*Convolvulus arvensis*) and hedge bindweed (*Convolvulus sepium*). Four hundred to 480 pounds per acre were sufficient for first treatment. The spray solution (2 pounds per gallon) used was double the concentration employed by Grau (43). They recommend that application be made in autumn or in summer if the season is one of ample moisture.

Zahnley and Pickett (122) have used a solution of sodium chlorate, one pound per gallon of water, 150 to 200 gallons per acre, as a control of bindweed by making three successive applications in August, September, and October.

Light applications to the soil of compounds of zinc are occasionally made as a control in zinc deficiency of certain plants or as a remedy in plant disease. Neidig and McCallum (84) have patented a zinc chlorate mixture as a herbicide which may warrant experiments in weed control on areas deficient in zinc. The patented mixture consists of a chemical combination of zinc sulfate and sodium chlorate in which the zinc salt is present in excess of the amount required to balance chemically in combining with the sodium chlorate. However, the mixture is not recommended for cultivated lands, but rather for railways and highway right-of-ways.

Pulverized or finely ground chlorate added to limestone, raw rock phosphate, sand or other carriers are proposed from time to time as more efficient and economical than water solutions of chlorates. Under "Fire Hazards" mention shall be made of a report by Grau (42) in which it is claimed that weeds destroyed by chlorate powder mixtures are less liable to be ignited by spontaneous combustion than the same weeds destroyed by chlorate solutions. In describing his experiences with powdered chlorate mixtures, Willard (117) states that mixtures of finely ground sodium chlorate and limestone do not have a tendency to cake and, in preliminary trials, have given satisfactory results in weed control.

There is quite a variety of patented herbicides on the market which contain the chlorates of either sodium or calcium (or both) and, in some cases they carry, in addition, an absorber of moisture such as calcium chloride or magnesium chloride. An illustration of a product of this character may be found in the description of a patent granted to R. N. Chipman (28) in Germany. The herbicide consists of a mixture of 2 parts of calcium chloride and 3 parts of sodium chlorate. Another patent granted to Heath (54) in the United States describes a similar product crystallized at a temperature above 60° C. from approximately an equimolecular solution of calcium chloride and calcium chlorate.

For the eradication of perennial weeds, Arny, Bridgford and Dunham (3), at the University of Minnesota, apparently did not find it necessary to employ a sodium

chlorate solution greater in concentration than 12½ per cent (one pound chlorate in one gallon of water). They applied the solution as a spray at 125 to 150 pounds pressure to the tops of living weeds and used dry chlorate when weed foliage was partially dead. They found these treatments effective regardless of weather conditions, but recommend that the applications be made when the weeds are in bloom or when they are nearing maturity. These investigators state that it is desirable to wet the weed tops thoroughly and that as much solution as 2 gallons per square rod may be required.

### *Dry Chlorates:*

At the present time, on some Hawaiian sugar plantations, consideration is being given to the use of dry or slightly moist herbicide powders for application to weeds (not the soil) as a substitute for the liquid spray. The purpose, of course, is chiefly a matter of reducing the costs of providing, transporting, and handling large quantities of water. In a discussion between the author and Raymond K. Conant, Agriculturist, Olaa Sugar Company, Ltd., a tentative formula for such a powder, it was agreed, in addition to a concentrated weed poison, should contain a small percentage of a bland oil to function as a leaf "sticker" and dust inhibitor, and a small quantity of a caseine glue to facilitate leaf adherence in rainy weather. A large proportion of pulverized raw rock phosphate might be used as a carrier and diluent. Eventually such a powder would reach the soil and in most cases the phosphate rock it contained might well form a part of the next scheduled fertilization. The fraction of weed toxin in this proposed mixture must be selected with due consideration being given to its residual effect on soil and the subsequent crop. If the area to be treated were to be left in fallow for a half-year or more in wet, warm country, chlorates may be used, perhaps, with no ill aftereffects.

The use of chlorates in an area to be maintained in continuous cultivation might prove unwise because of chlorate soil sterilization. Muenscher (83) has found in New York State that the application of dry sodium chlorate, in late autumn, directly to the soil surface (200 to 600 pounds dry chemical per acre, in one application) destroys deep-rooted perennial weeds during the ensuing winter, but that the chlorate is decomposed only to a point by *the following summer* which would permit *some* crops to be grown. Many other workers report more active and longer chlorate soil sterilization. Additional comment on this point will be made later.

### *Effectiveness of Chlorates:*

Users of chlorates do not invariably agree on the effectiveness of this chemical in destroying weeds.

Walker (115) at Hana, Maui, it was noted, sprayed above-ground portions of weed plants with a 5 per cent sodium chlorate solution and also "fairly well soaked" the ground at the base of the plants with the same solution. He reported that 2 or 3 applications of the spray at intervals of 2 or 3 weeks were required for a complete kill, although small weed patches were eradicated by a single treatment.

Using a maximum of 200 pounds of sodium chlorate per acre, Wakabayashi (114) claims to have destroyed the underground portions of weeds, but he added that it required 2 to 3 months to accomplish this.

Crafts (33) found chlorate treatment of weeds most effective, as did Walker, by applying the chemical to both soil and plant. He states that in many cases weed roots were destroyed 3 feet below the soil surface and that a thorough single spraying was usually as effective as 3 light applications.

In general, experimenters with chlorates find the sodium salt more effective than others which may compete with it in equivalent concentrations or on a cost basis. Meadly (76), in Australia, supports this statement; likewise do Thornton and Durrell (108) in Colorado.

Complete eradication of white top (*Erigeron annuus*) was accomplished by Hulbert, Spence and Benjamin (57) using 2 applications of chlorates 10 days apart. A third treatment was no more effective.

When depending upon chlorates to destroy weed roots, conditions in the soil approaching optimum warmth and moisture favor effectiveness of treatment. On the other hand, in dry soil, even in warm weather, Davidson (35), in Idaho, found chlorates quite ineffective. Warmth and moisture appear to be essential if maximum herbicidal action of chlorates are to be realized. Good drainage must be assured if toxic aftereffects are to recede in a reasonable period of time.

Many observers, who appear to be qualified to make such statements, claim that applied chlorates are absorbed by weed surfaces and subsequently are translocated throughout the plant. The net result is its ultimate demise.

Loomis, Smith, et al (73), for instance, state that apparently sodium chlorate penetrates all the external surfaces of the plant with the exception of that part having unusually heavy cuticle. After penetration, they state, its movement within the plant is by the xylem and is most rapid in the direction of the transpiration stream. These investigators state further that chlorates may be absorbed by the roots and rhizomes of plants and thence be translocated to the tops. In such cases, the entire plant is destroyed.

On the contrary, Aslander (4) published experiences, the substance of which appear to indicate that no harm occurred to the roots of thistle (*Cirsium arvense*) when a chlorate spray was applied so that no solution reached the soil. Direct applications to any part of the root system killed the tops in a few days, but the only portion of the root which died was that part which came in *direct contact* with the chlorate solution. He stated that chlorates can be transported through a root system without harming the parts through which the transportation takes place and that in order to kill all the roots of a plant, chlorates *must* be applied over the entire area where roots occur.

Under some conditions of soil and climate (dry and cold, for instance), applications of chlorates may not reach a maximum efficiency until warm, moist weather sets in. Hulbert, Rembsberg, and Spence (56) agree in this regard. They found that the full effectiveness of a chlorate weed treatment was not manifested until the following season. They recommend that chlorate-treated areas not be irrigated and state that complete destruction of weeds does not follow with sufficient regularity to support the belief that single applications of chlorates are ample and generally satisfactory. This finding is general and quite common.

In his experiment with Johnson grass (*Sorghum halepense*), Harper (51) ~~was~~ did Walker (115), found 2 or 3 sprays necessary to eradicate the pest. Harper also

stipulates that when Johnson grass may be cut with a mower, the first stand should be mowed when incipient heading occurs; then follow with the spray after the ratoon reaches a height of 12 to 18 inches.

*Aftereffects of Chlorates on Crops, Soils, Humans and Animals:*

Most experimenters agree that chlorates sterilize the soil to a greater or less extent, but there is little unanimity among observers regarding the duration of the sterilization. The reason for this wide divergence in opinion is no doubt due to the fact that observations are sometimes made and recorded without correlating in greater detail climate and weather or moisture and organic relationships in the soil.

Bickmore (17) states that chlorates are decomposed in soil during the winter and as a consequence do not affect the following spring plantings or the subsequent crops. This statement might be made more specific if it included data upon snow and rains in winter, warmth in early spring and porosity of the soil.

Crafts (34) found that continual leaching of the soil with irrigation water was the best method extant of clearing land of residual sodium chlorate. In his experience, areas which had become sterile as a result of chlorate weeding practice 3 years previously were returned to productivity by leaching them with 36 inches of water. This accomplishment was made within a single season. (Open, porous soil is assumed, of course.)

Crafts (34) differentiated between soil types in noting toxicity effects of chlorate applications. He found toxicity highest in an adobe and lowest in a clay, but 40 cm. of water was sufficient to remove the chlorates by percolation, from the clay soil. He found much less fixation of chlorates than of arsenic in four soils which were studied.

As to the toxic effect of chlorates, an examination of the structural formulae of sodium chlorate, as an example, reveals two loosely combined oxygen atoms with double bonds ( $\text{Na} - \text{O} - \text{Cl} \begin{smallmatrix} \text{O} \\ \parallel \\ \text{O} \end{smallmatrix}$ ). This structure denotes instability, particularly in the presence of organic or other reducing matter. Upon reduction of the chlorate, nascent oxygen is released. Apparently this active oxygen is the component of the chemical which destroys plant life, weed or otherwise, for Aslander (4) states that probably oxygen attacks the sensitive part of plant protoplasm and, by inference, is responsible for its collapse. One type of compound which should arrest the toxic action of a chlorate in the soil and thereby assist in reclamation of the soil would chemically be opposite in character to the oxidizing chlorate, i.e., a reducing agent.

It is interesting to find the record of a patent granted Ehrhardt (38) for a number of soil reconditioning processes to be used following a soil chlorate-weeding application. Among the compounds he describes are ferrous salts, hyposulfites, and nitrites. Another type of soil reconditioner for chlorate damage is set forth in this patent as a substance which accelerates catalytically the decomposition of residual chlorates. Magnesium chloride is an example of reconditioners of this character.

Anent the toxicity in the soil of chlorates there is reason to believe, in some open soil types, that weak solutions of chlorates may be used regularly and with impunity. Woodman (119) reports that wheat has been sown safely without ill effects after spraying a field area with one per cent sodium chlorate. (This is about one-tenth

the concentration usually used.) But with solutions of higher chlorate concentration, he states that sowing should be left until the following season, *depending on the nature of the soil and climatic conditions*. Any one of the negative dependent conditions would justify jumping a season, no doubt, such as a tight soil, cool weather or scant rainfall.

Shear (96) found that the growth of mushrooms was enhanced on plots in which sodium chlorate was used to destroy quack grass (*Agropyron repens*). Comparison was made on a similar area of untreated soil. He speculates on the cause, suggesting that lack of competition, increased available food materials or direct chlorate stimulation may have accounted for the increased mushroom growth. This published experience has been the only one encountered where a possible direct benefit to plant development has been suggested as due, possibly, to a chlorate.

Loomis, Smith, et al (73) have found that chlorates, whether applied direct to the soil or reaching the ground from sprayed plants, remained unchanged for a period of 2½ years. Statements such as this are frequently met. These investigators add that removal of chlorates from the soil by leaching requires large quantities of water. They are inclined, from their observations, to ascribe decomposition of chlorates as the principal method of their becoming non-toxic in soils (not by leaching) and have found decomposition to take place with fair rapidity in moist soil at temperatures above 20° C. A statement appears in a circular by Arny, Bridgford and Dunham (3) to the effect that in Minnesota, when about 500 pounds per acre of chlorates are applied to the soil, sterile conditions remain in that region from 7 months to a year or longer.

In contact with the skin, chlorates do not appear to be harmful to humans and when consumed by grazing animals on sprayed vegetation, they do not, it seems, occasion any injurious results. Megee and Hudson (78) state that sheep were grazed without ill effects upon meadows recently sprayed with sodium chlorate. Latshaw and Zahnley (69) support this observation for they appear also to have found sodium chlorate non-poisonous to livestock which had grazed on chlorate-treated vegetation.

Apparent contradictions to these findings may be found, but it should be emphasized that, as a rule, where chlorates are reported as harmless to stock, it is *after* applications of the chemicals to weeds or grass. Destruction of weeds by chlorate sprays undoubtedly decreases the potency of the chlorates in the process and leaves a saline residue containing little, but, nevertheless, some of the original chemical. Given directly to animals, Seddon and McGrath (95) report 2 to 3 ounces of sodium chlorate as fatal to sheep within 24 hours and ⅔ ounce of the same chemical, consumed by a steer daily for about 2 weeks, was fatal to this animal. In these cases the animals took the chlorates directly into their systems and not after the chemical had acted on vegetable matter.

#### *The Fire Hazards of Chlorates:*

An undecomposed residue of dry chlorate in fine division and distributed over a large area of dry or dead weeds or grass is unquestionably a serious and real fire hazard. Conditions of partial dryness may be more hazardous. In the former case but a spark is needed to set off the entire area in a fierce blaze. In the latter case,

under favorable combustion conditions, a fire may break out spontaneously. Either type of fire may occur a few days after a chlorate weed spraying for the conditions necessary to favor either set of circumstances may easily develop.

It is a matter of record that really disastrous fires of such a nature have seldom been reported.

The chemical similarity of chlorates (in intimate contact with dry plant material) to gun powder (chlorate of potash and charcoal) has been recognized by investigators of herbicides and measures have been developed to reduce this hazard. Unfortunately this danger is not confined to dead weeds and grasses. Chlorate solutions, even when modified to reduce the field fire hazard, are dangerous in the extreme when spilled on the worker's clothing or upon combustible materials in warehouses and sheds. In both cases chlorates may accumulate by repeated and successive spillings. The warmth of a man's body, with exposure to sun and wind, may readily drive out the protective moisture of the calcium chloride or other moisture-absorbing agent placed in the spraying compound to reduce the fire hazard in the field. Under conditions such as these, a spark or match flare may envelop in flames a garment which has previously been moistened with a chlorate solution. In the case of the chlorate-soaked refuse in warehouse or shed, spontaneous combustion is definitely invited.

Therefore, it is significant to find, in the published works of research investigators studying chlorates, repeated warnings to others to avoid spilling the chlorate solutions on the clothing or on refuse. The chlorides of calcium or magnesium are usually added to chlorate spray solutions to reduce the fire hazard after application of the spray by the ability these compounds possess for absorbing and retaining moisture, even from the open air on a clear dry day. Bickmore (17) states that equal quantities of a chlorate and of calcium chloride, or  $\frac{1}{3}$  by weight of magnesium chloride and  $\frac{2}{3}$  by weight of a chlorate, render the mixtures safe as far as fire in the sprayed area is concerned. These additions reduce the herbicidal action of the chlorate, however.

It has been found that broadcasting dry chlorates materially reduces the fire hazard as compared with the more evenly distributed chemical in fine division on weeds dried out after spraying. Gray (44) states that the dry chlorate application, when made with due precaution, eliminates the fire risk which accompanies the use of chlorate solutions.

In a study made by Cook (29) on the combustibility of organic matter and chlorates in various proportions at different relative humidities, he determined that mixtures containing more than 10 per cent sodium chlorate are hazardous below 75 per cent relative humidity. Also that admixtures of calcium chloride or magnesium chloride with sodium chlorate render the mixture safe when these moisture-absorbing salts form  $\frac{1}{2}$  to  $\frac{1}{3}$ , respectively, of the resulting herbicide. Furthermore, he states that the sodium chlorate-magnesium chloride mixture is the most effective "safe" herbicide, but it is only about half as efficient in weed-destroying ability as pure sodium chlorate.

The author (50) has found that additions of sodium stannate or sodium phosphate to sodium chlorate solutions also reduce the fire hazard of these sprays.



### *Summarizing the Discussion on Chlorates:*

*Applications of chlorates:* As a spray for general purposes, dissolve one pound of sodium chlorate and one pound of calcium chloride in sufficient water to make one gallon of finished solution. Apply 150 to 200 gallons of the solution per acre, then repeat the treatment twice at intervals of about 3 weeks.

As a dry application, broadcast a mixture of 12 pounds sodium chlorate and 100 pounds powdered dry sand, limestone or raw rock phosphate. Use 5 pounds of the mixture per 10 square yards of weed carpet.

*Effectiveness of chlorates:* There is ample evidence to support the statement that sodium chlorate (one pound per gallon in water solution) brought in contact with the weed root system and used at the same time to saturate the foliage will destroy that plant. Any less thorough application may or may not partially or entirely incapacitate the weed or suspend its growth for an indefinite period.

*Aftereffects of chlorates on crops, soils, humans and animals:* After application to vegetation (weeds, grasses, etc.) chlorates do not seriously injure stock which may thereafter graze on the treated plants. Aston and Bruce (6) state that fatal burnings of human beings have been recorded as a result of using sodium chlorate sprays. Chlorates applied to soil definitely sterilize that soil for periods which may vary from a few weeks to a few years. The duration of sterilization should be least for any given quantity of chlorate in an open porous soil containing organic matter, subject to heavy rainfall or frequent irrigation in a warm climate.

*The fire hazards of chlorates:* Undecomposed chlorates on dead weeds in dry sunny weather constitute a serious fire hazard. Accumulation of chlorates on clothing are dangerous. Spilled on refuse or in contact with any combustible material, chlorates may decompose and supply oxygen in quantities sufficient to start spontaneous combustion.

Chlorates used in weed control are protected against fire risk in the field by including in the spray solution as much as an equal weight of calcium chloride per weight of sodium chlorate used. This protection reduces the tendency for a loss of moisture to take place in dead weeds to a point of tinder dryness. It does not prevent spontaneous combustion in combustible material situated in poorly ventilated places.

### OIL SPRAYS

A great number of oils have been used in weed control, but of these the most effective (cost considered) appears to be Diesel oil. Oils destroy weeds by contact and, although they are absorbed by weed tissues more readily than are aqueous herbicides, they do not always destroy the weed roots. However, as a class, oils are one of the few substances commonly used which do render weed seeds impotent.

Two of the outstanding advantages of using Diesel oil for weed control on plantation railroad right-of-ways may be stated as: (a) the oil is harmless to the rails; and (b) at the same time it is beneficial to the ties.

In Hawaii, Diesel oil has been used extensively by several plantations and in experimental weed control by Denison (37) at rates of 100 to 300 gallons per acre. Denison found the application of 155 gallons per acre on shorn weeds more effective than 275 gallons applied to larger and heavier growths. The extra cost of Diesel oil, compared to other sprays, was offset by the reduced costs of labor in covering the

same area by non-poisonous sprays. In general, oils cannot compare with arsenicals, either in cost or in effectiveness, for weed control. When purchased for weeding practices, Diesel oil should meet the specifications submitted by Normann (85) in a report on the subject which occupies the entire issue of the February 1937 number of *Public Roads*. His specifications follow:

Specific gravity (A.P.I.) at 60° F.—not less than 27° Baumé.  
Flash point (Penskey-Martin closed cup)—not less than 150° F.  
Viscosity (Saybolt Univ.) 100° F.—not over 50 seconds.  
Distillation (90 percent point)—not over 680° F.  
Water and sediment—not more than a trace.

Oil emulsions have been found quite satisfactory in California.

Johnson (64) states that a Diesel oil containing 2½ per cent of asphalt will emulsify readily with water and that this emulsion penetrates and destroys the weed seed burrs.

#### LESS COMMON WEED ERADICANTS

A brief description follows of some of the less frequently used chemical compounds in weed control.

##### *Ammonium Sulfate:*

(Quotation: \$35.43 per ton, f.o.b. Honolulu)

Ammonium sulfate  $(\text{NH}_4)_2\text{SO}_4$ , is a white or pale-yellow granular salt freely soluble in water. It forms a water solution which is acid to litmus paper. It reacts chemically with lime and alkalis, liberating free ammonia. It produces, at first, a temporary acidity when applied to the soil. This induced soil acidity is rapidly dissipated unless frequent or recurrent additions of the chemical are made. The eventual effect of long-time applications of sulfate of ammonia to the soil is said to bring about a loss of soil bases and a permanent increase of soil acidity.

Sulfate of ammonia is used extensively as a fertilizer and as a constituent in compounds used to repel flames or fires. The purified chemical does not cake in storage, but in a confined space it liberates ammonia in small amounts. Applied to the soil it exerts a toxic action to common weed growth, but at the same time it stimulates and fertilizes grasses of all kinds (including sugar cane). Its purchase price is governed by the market value of its nitrogen fraction.

One hundred to 400 pounds per acre, applied in dilute solution or dry-mixed with sand or other carriers, will tend to reduce weeds in lawns and greens.

According to Blackman (19), occasional applications of sulfate of ammonia on grass plots not only reduced the weeds but did so without producing a significant change in soil reaction—an important consideration already referred to above and again below.

When applied at the rate of about 130 pounds per acre every two weeks during spring and summer, Blackman (18) states, in another paper, that this treatment diminishes the weeds and increases the area covered by grasses. He states that soil acidity is not a prerequisite for weed reduction by sulfate of ammonia, the toxic effect probably resulting from the differential action of ammonium ions, which are toxic to most species of weeds, whereas they increase the growth of grasses. He

also observed that equivalent mixtures of ferrous sulfate and ammonium sulfate produced a greater reduction in weeds than did sulfate of ammonia alone.

Long (72) advocates the use of lawn dressings consisting of 3 parts sulfate of ammonia, one part calcined sulfate of iron and 20 parts sand. The mixture should be spread at intervals of 2 weeks during growing season at the rate of  $\frac{1}{2}$  pound per square yard. He states that this mixture is very effective in reducing broad-leaved species of weeds. As a fertilizer on lawns it is excellent.

Jaquenaud (62) found that very dry and finely powdered sulfate of ammonia acts as a strong herbicide when used at the rate of 300 to 400 kilograms per hectare (about the same figure in pounds per acre). He says that it is too active for use with cereals, but that its severity can be reduced by diluting  $2\frac{1}{2}$  parts of ammonium sulfate with an equal quantity of sylvite (native potassium chloride) and  $1\frac{1}{2}$  parts of finely ground (rock) phosphate.

#### *Ammonium Persulfate:*

(Quotation: in kegs, 21¢ a pound, f.o.b. New York)

Ammonium persulfate  $(\text{NH}_4)_2\text{S}_2\text{O}_8$  is a white, crystalline substance. In closed containers, protected from sunlight, it will keep for years unchanged. Exposed to light, air and moisture in contact with organic substances (plants and weeds), it decomposes the plant material by charring but does so without danger of causing fire. It is a powerful oxidizing agent, being similar in this respect to sodium chlorate. It is very soluble in water, the solution so formed slowly decomposing and giving off "ozonized oxygen." Its toxic effect upon vegetation is due to its oxidizing and to its charring properties.

In a circular issued at the University Farm in St. Paul, Harvey (52) reports the results of a preliminary study of this chemical. It appeared to have a more potent action on some weeds than did ammonium sulphocyanate. Pound per pound, it was equivalent to sodium chlorate in weed-destructive action. It appears to decompose in the soil and thereby yield nitrogen and sulphur as fertilizer. It has the disadvantage, however, of attacking brass, copper, iron and zinc. It does not affect rubber or aluminum.

#### *Ammonium Thiocyanate (also called Ammonium Sulphocyanate):*

Ammonium thiocyanate,  $\text{CNS}(\text{NH}_4)$ , occurs in gas liquor and in crude coke-oven by-product liquor. It is also formed by heating a mixture of carbon disulphide, concentrated ammonia and alcohol. It crystallizes in colorless plates soluble in alcohol and in water. It is unstable in the presence of organic matter, contact with which causes it to break down into simpler products. Its value as a fertilizer is questionable when considered upon a cost basis of the commercial chemical. As a constituent of "gas liquor" its cost is materially reduced.

This compound is another dual-purpose weed eradicator. Claims are made by some experimenters that it supplies nitrogen and sulphur after it kills weeds and is itself decomposed and rendered non-toxic in the process. Harvey (52) states that its harmful action on vegetation, other than its action by contact with weeds, is destroyed by soil bacteria. He recommends that from 320 to 480 pounds be applied

per acre in solution at intervals of from 4 to 6 weeks. He stated in a later paper (53) that its toxic action is less persistent in the soil than that produced when chlorates are used. Toxicity disappears in 3 months after an 800-pound application and in one month following a 320-pound application. It appeared to stimulate desirable plant growth after its toxic action subsided.

Unlike chlorates, Harvey states that it is not explosive when mixed with organic materials. As a weed eradicator, it tends to keep the dead plants moist until it is leached off by rain.

Its disadvantages are its cost (about 20 cents a pound) and its corrosive action on metals and leather. It does not attack rubber.

Aston, Bruce and Thompson (8) report results similar to Harvey's. They found a dry mixture of ammonium sulphocyanate one part, with super phosphate 3 parts, effective in the control of unmowed ragwort (*Senecio sp.*) at the rate of 400 pounds per acre. Referring to the claims made that these cyanates function as fertilizers in addition to killing weeds, Skinner and Sandhoff (97) found that only half of the nitrogen of ammonium thiocyanate can be considered as available fertilizer.

Experimenters with thiocyanates frequently recommend that, when it is obtainable, a by-product crude liquor containing this chemical be used in preference. This thiocyanate liquor also contains tarry residues. Its effectiveness in weed control is said by Long (72) and others to be superior to solutions of the chemical alone. Stock will not graze on vegetation sprayed with thiocyanates because of the unpleasant taste. Ball, et al (12), state that ammonium thiocyanate is ineffective in California. Its use in Hawaii has been disappointing.

#### *Borax (Sodium Borate):*

(Quotation: tech. cryst., \$56 to \$67 a ton, delivered)

Borax, or sodium borate, is a white, gritty, granular substance which is refined from natural deposits occurring in dry inland lake beds of California and other places throughout the world. Borax is not freely soluble in water. Less than 2 per cent can be dissolved at 50° F. It forms a mildly alkaline solution in water, a property which renders it satisfactory as a gentle detergent.

Borax is used extensively in industry and in the arts, but its effect on plant life is frequently toxic, even in small quantities. In minute amounts, borates have been found essential for the normal growth of a number of plants.

Because of comparatively low solubility, borates are used as dry applications in weed control. Ball, et al (11), state that borax and borate ores are cheaper and more persistent in effect than are chlorates. A combination of one part of sodium chlorate and 8 parts of borax applied dry at 4 to 16 pounds per square rod makes a satisfactory weed eradicator, according to these investigators. Users are warned that borates are dangerous compounds to use on citrus fruits, deciduous fruits, grapes, nuts and certain ornamentals.

#### *Calcium Cyanamide:*

(Quotation: 21-22 per cent N, pulverized, in bags, \$1.15 per  $\text{NH}_3$  unit)

Calcium cyanamide,  $\text{CaNCN}$ , is prepared by heating calcium carbide and nitrogen to a temperature of 1100° C. It is a dark gray, granular substance which dissolves

in water, forming dicyandiamide, a product which decomposes readily in the soil, yielding the elements of ammonia.

Calcium cyanamide is another compound used in weed control which contains plant nutrients as its principal constituents. This product is a commonly used nitrogenous fertilizer. It has distinct weed-inhibiting properties and crop recovery is, as a rule, positive and rapid. About 60 per cent of the weight of calcium cyanamide is essentially active lime and hence its use on soils low in calcium may be quite beneficial. It contains about 21 per cent nitrogen; thus, it is comparable to sulfate of ammonia on a nitrogen basis. It has the advantage over sulfate of ammonia in not contributing to increased soil acidity nor to the loss of desirable soil bases. Applied dry, either powdered or granulated, at the rate of 500 pounds per acre when weeds were 1½ inches high, Smock (99) states that it effectively controlled annual weeds throughout the cutting season.

Calcium cyanamide appears to be very effective in the control of weeds on lawns and golf greens. Sturkie (105) treated a badly weed-infested Bermuda grass (*Cynodon dactylon*) green with this chemical by application of 800 pounds per acre on the dormant grass. The weeds were killed and the nitrogen added stimulated the later growth of grass. On a lawn of various perennial grasses, he destroyed the weeds by applying 1000 pounds or more of the cyanamide and noted that while the grass was seriously burned, it soon recovered and grew vigorously.

In larger scale chemical weeding operations, calcium cyanamide has been used with a fair degree of success. Korsmo (68) describes the dusting of weedy cereals with this compound when they were covered with dew. The treatment was beneficial to the grain and reduced weeds about 75 per cent.

Jaquenaud (61) describes a powdered weeding mixture which consists of cyanamide, sylvite (native chloride of potash) and sulfate of ammonia. Incidentally, this mixture is a complete fertilizer.

#### *Carbon Bisulphide (Carbon Disulphide):*

(Quotation: in 55-gal. drums, \$0.05 a pound, f.o.b. New York)

Carbon bisulphide,  $CS_2$ , is a volatile, explosive, foul-smelling liquid which may be produced by passing sulfur vapor over red-hot charcoal. Carbon bisulphide boils at 46° C., a few degrees higher than body temperature. Its vapor is 2⅓ times heavier than air; when mixed with air, it is highly and violently explosive. When breathed in small quantities over a period of time it is injurious to health. If taken into the lungs not sufficiently diluted with air, its action is fatal.

Carbon bisulphide is employed for weeding purposes in very difficult stands of persistent perennial weed pests in small areas or where cost and hazard may not forbid its use.

It is very inflammable, entails heavy loss by evaporation, and is expensive.

When used properly, carbon bisulphide completely destroys the weeds it contacts. Ball, et al (11) describe a carbon bisulphide weeding procedure whereby holes are made in the soil 18 inches apart each way in staggered rows over an infested area to be treated. Two to four ounces of the chemical are poured in each hole. The depth of the application is important. If there is ample moisture in the surface soil, the application should not go below 6 inches. If the surface soil is dry, it will have

to be placed at a lower depth, but if it is placed too low, the vapor of the chemical (being much heavier than air) may not contact the root crowns in sufficient concentration to destroy them. In any case, immediately after pouring the chemical, the holes should be filled with moist soil and carefully tamped. Complete diffusion of carbon bisulphide will take place in the treated soil in about 3 to 6 weeks. After this period the soil will be found unaffected for subsequent crops. This is an expensive but a very effective method for eradication of guava (*Psidium guajava*), lantana (*Lantana camara*), gorse (*Ulex europaeus*), etc.

As an illustration of the unusually effective herbicidal properties of this chemical, Ball and Robbins (13) report that the very obnoxious and difficultly eradicated camel thorn (*Alhagi camelorum*) (in California) can be destroyed by carbon bisulphide with a thorough treatment of the soil to a depth of 10 inches.

Rodgers and Hatfield (92) applied the chemical in holes 12 to 18 inches deep, 2 feet apart, in controlling other perennial weeds of persistent characteristics.

### *Copper Sulfate:*

(Quotation: 99 per cent cryst., in barrels, \$5.00 per 100 pounds, f.o.b. New York)

Copper sulfate,  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  is the "bluestone" of commerce. It may be prepared by dissolving copper metal in sulfuric acid, blue crystals separating out on cooling. It is readily soluble in water, forming a weakly acidulated solution.

The toxic action of bluestone on certain vegetation is a mild but effective one when its water solution is applied properly diluted. It is used commonly to destroy algae and similar plants in reservoirs, ponds and even in fish aquariums. It is not used to any great extent in large areas but Long (72) states that cereal crops are rarely damaged by sprays containing 3 to 5 per cent of copper sulfate, 40 to 100 gallons per acre. He notes that a temporary check may be given the cereal. The same observation applies to peas, beans, and vetches when so treated, but they recover satisfactorily from any preliminary injury.

In experimental weed eradication on garden paths at Craibstone in Scotland, Hill (55) applied one pound of powdered copper sulfate per 100 square feet with an additional one per cent solution of sodium chlorate. It gave good results, but the efficiency of both compounds decreased with increased rainfall during the first week of applications. A mixture consisting of one part of copper sulfate and 3 parts of concentrated sulfuric acid (60° Bé.) has been patented in England by Litsche (71) as a material recommended for the destruction of weeds in growing crops.

In a report of the Nova Scotia Department of Agriculture (86) the statement is made that a 3 per cent solution of copper sulfate applied as a spray upon grain when it was approximately 4 inches high gave excellent control of cadlock (*Brassica arvensis*).

### *Dyes:*

Claims are made by Truffaut and Pastac (110) that certain organic dyes in water solution are destructive to plants and weeds. Unsulphurated acid dyes exert a marked action on herbaceous plants which varies with age and nature of plants, the amount of dye used and the wetting power of the solution. Wild mustard (*Brassica*

*arvensis*) or thistle (*Cirsium arvense*) can be destroyed in wheat and oat fields, using a properly prepared dye solution, without injury to the cereals. Similarly, certain weeds in lawns may be destroyed.

*Iron Sulfate (Copperas—Green Vitriol):*

(Quotation: cryst., gran., in barrels, \$16.00 to \$17.00 per ton, works)

Ferrous sulfate,  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$  is a pale-green, glass-like crystalline compound which may be prepared by dissolving scrap iron in sulfuric acid. It dissolves in water, forming an acid solution which is rapidly decomposed by the oxygen of the air.

Aslander (5) reports that ferrous sulphate solutions were effective at high relative humidity in killing wild mustard. At low humidity, little injury was noted. He adds that ferrous sulphate destroys plants by direct chemical action and not in withdrawal of water from plant tissue by plasmolysis.

Applied to weed-infested cereals at a concentration of 15 to 25 per cent, about 300 gallons per decare (1200 gallons per acre) when weeds and cereal were small, weeds were reduced about 80 per cent and the grain (oats) was increased about 25 per cent. Wild mustard (*Brassica arvensis*) was destroyed in fields of oats or barley by Viger (113) without great injury to the grain by spraying the weeds with a 20 per cent solution of ferrous sulfate, 100 pounds of the chemical per acre.

Normann (85) states that grasses and grain are very resistant to ferrous sulfate spray and although it causes them to become black when first sprayed they soon recover. He adds that the spray is most effective when applied on humid days when rain is not likely to fall. Rain, he says, washes off the solution and in very dry weather the solution may evaporate from the sprayed weeds, leaving a residue which falls off the leaves before they are affected. Evidently ferrous sulfate is not a generally satisfactory herbicide. It has the added disadvantage of discoloring buildings, walks and clothing. However, it is very effective in the destruction of garden snails and slugs.

*Kainite:*

Kainite,  $\text{K}_2\text{SO}_4 \cdot \text{MgSO}_4 \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ , is a naturally occurring fertilizer having weed-destructive properties. It contains approximately 35 per cent potassium sulfate, 24 per cent magnesium sulfate and 19 per cent magnesium chloride.

It has been used satisfactorily to combat weeds upon areas low in potash. It appears to have the ability to withdraw moisture from the inner tissue of the weed plant.

Long (72) places its practical limits of application at from 400 to 800 pounds per acre applied in warm, dry weather, early in the morning, upon weeds wet with dew. As a weed killer and a fertilizer it may be applied dry as a mixture of 5 parts kainite with one of cyanamide at the rate of 500 to 600 pounds of mixture per acre. Long has found this application very satisfactory.

Demela and Brada (36) report that an application of 550 pounds of finely ground kainite and 135 pounds of calcium cyanamide per acre was effective for 2 years against a number of common weeds. Husemann (59) experimented with

kainite, using very finely powdered dusts. He also studied the effects upon weeds of using kainite having a high or a low chloride concentration. He found that increases in fineness reduced the tendency of the dust to form aggregates and, as the chloride fraction of the compound increased, its herbicidal action was improved.

Sturber (104) described a long-time effect of kainite in destroying weed growth in which a plot treated in 1927 with 1071 pounds of kainite per acre (in fine powder) to destroy charlock (*Brassica arvensis*) in oats remained clear of the weed when oats were again grown in the same plot in 1932. A control of weeds which infested cereal on a moss peat soil was obtained by Brune, Husemann, et al (25) by the application of from 150 to 650 pounds of kainite per acre 4 to 5 weeks after sowing the summer crop or about the middle of November with the winter crop.

Butler (26) has found that one pound of kainite per 10 square feet of poison ivy (*Rhus toxicodendron*), dusted on the wet foliage, is usually sufficient to kill this pest. Complete eradication may be obtained by applying a second or a third application.

#### *Sodium Bisulphate (Nitercake):*

(Quotation: in bulk, \$16.00 per ton, works)

Sodium bisulphate,  $\text{NaHSO}_4$ , is an acid salt, soluble in water. It is prepared by heating sodium sulfate with sulfuric acid and allowing the mixture to cool, whereupon the acid sulfate crystallizes out. This compound attacks common metals. Its use in the laboratory is confined chiefly to the removal of fused metallic oxide residues from platinum apparatus.

Long (72), in his text on chemical weed control, credits French with having learned that 20 per cent solutions of sodium bisulphate will destroy charlock (*Brassica arvensis*) in cereals at all stages of growth. On very heavy growths of weeds, an application of 350 pounds of sodium bisulphate per acre has been made in a 45 per cent solution. Long notes that bisulphates have been found effective in controlling aquatic weeds.

#### *Sodium Bisulfite:*

(Quotation: powdered, in barrels, \$3.35 to \$3.60 per 100 pounds)

Sodium bisulfite,  $\text{NaHSO}_3$ , is an acid salt of sulphurous acid. It attacks plant materials because of the ease with which it becomes decomposed, liberating, at the same time, free sulphurous acid vapor. It is used extensively in bleaching.

Aston and Bruce (6) and Kolzov (67) report that satisfactory eradication of weeds may be accomplished using dusts or solutions of sodium bisulfite on lawns, gardens and paths.

Aston, Bruce and Thompson (8) describe comparative experiments carried out with sodium bisulfite, potassium bisulfite and sodium-ammonium bisulfite for control of ragwort (*Senecio sp.*). In some instances the weed was completely eliminated, using 10 per cent solution of either the sodium or potassium compounds. In other cases, weed-destroying properties were feeble. Applied on lawn weeds, grass was temporarily affected, but soon recovered.



### *Sulfuric Acid:*

(Quotation: in carboys, \$1.25 to \$1.50 per 100 pounds)

This chemical has been used extensively in Europe for weed control. Its use in America for the same purpose has become much more general during the past few years. Sulfuric acid is supplied by the manufacturer usually in glass carboys in concentrated form (60° Bé. to 66° Bé.). More concentrated acid may be shipped in steel tank cars or steel drums at weather temperatures above freezing.

Any concentrated form of the acid is a heavy, oily liquid which will severely burn a person or his clothing, will corrode all base metals except steel and will destroy rubber. When water is *added to* concentrated sulfuric acid, it will combine chemically with explosive violence. Highly diluted sulfuric acid attacks all common metals including steel and iron, but it does not affect rubber nor is it critically dangerous when spilled on the body or on clothing.

Brought in contact with any common organic substance, sulfuric acid will decompose that substance by charring and in the reaction release and absorb the "elements of water" (hydrogen and oxygen) which the substance may contain. In spite of its dangerous chemical properties it is a substance not difficult to handle or manipulate, providing two important precautions are observed: (a) Never allow the concentrated acid to come in contact with any part of the body or clothing, and (b) in diluting this acid always add the concentrated liquid acid in a slow stream to a large volume of water, stirring constantly. The diluted acid attacks the metal of weed-spraying equipment. It is a very active herbicide toward shallow-rooted annual weeds. It is less effective on grasses and deep-rooted perennials, but does check their growth.

Its mild destructive action on grasses and cereals suggests its experimental study as a herbicide in sugar cane fields.

Long (72) states that 7 per cent to 10 per cent solutions of crude sulfuric acid in water are effective against a great variety of annual and biennial weeds. He regulates the time of spraying with age of weeds and crop—4-leaf stage in charlock (*Brassica arvensis*), for instance, in cereal 3 to 7 inches high. He advises the user to spray during dry weather, but states that it is no disadvantage to apply the solution to weeds covered with dew and even a light rain on the day following the application will not seriously affect the results which are sought. He states further that all cereals (and perhaps sugar cane) may be sprayed with safety and that any slight browning which results will most likely rapidly disappear. Also that the soil is in no sense injured by the small quantity of uncombined acid which may fall to the ground.

Ball (11) and his co-workers support the conclusions of Long which have just been enumerated. They have also used a sulfuric acid solution, 10 per cent in strength, with entire satisfaction in the control of a number of annual weeds in grain fields at the rate of 130 gallons of 10 per cent solution per acre. They observed marked increases in grain yields following this acid treatment of field weeds. They list the advantages of sulfuric acid sprays as:

- (a) Economical, costing one cent for one gallon of 10 per cent solution.
- (b) Neither poisonous to stock nor combustible.

(c) Decomposes weed tissue very quickly.

(d) Are not detrimental to the soil.

Blackman and Templeman (21) have employed 9.2 per cent solutions of the acid in control of yellow charlock (*Brassica alba*) and the relatively high concentration of 13.8 per cent acid in a 95 per cent control of white charlock (*Raphanus raphanistrum*). In both cases higher yields of cereal were obtained as compared with no acid treatment. It has been their experience that dilute sulfuric acid does not normally depress crop yields although in very dry weather some damage may occur.

MacDowall (74) secured a 70 per cent kill of white charlock (*Raphanus raphanistrum*) using an 8 per cent solution of sulfuric acid, 100 gallons per acre of barley. Using 75 gallons per acre of a 10 per cent solution, a 90 per cent kill of yellow charlock (*Brassica alba*) was realized. The barley wilted during the 24-hour period following the spraying (it was 4 to 6 inches high when the spray was applied), but it gradually recovered, he stated, and 18 to 20 days later it was much greener and more vigorous than similarly established unsprayed portions. Maturity was delayed 8 days by the treatment, but there was an estimated gain in the yield of grain of 20 per cent over the unsprayed portions. Not including overhead and other usual items of expense, the cost of the spraying per acre was about 10 shillings (\$2.50).

In summarizing his research using dilute sulfuric acid in weed control, Rabate (89) states that during a period of several years his experiences indicate that this acid acts as a fertilizer of the soil, destroys many weeds and many crop parasites. As to the fertilizer value of sulfuric acid in the soil, its virtue in this sense, it would seem, may be related to the solvent action it may have upon available nutrient or even to a lesser extent upon organic constituents of the soil. Braun (22) states a contrary opinion in this connection for he has found weeding treatments of grain with dilute sulfuric acid not to have any appreciable dissolving action in the soil upon the three principal nutrient elements. The fact remains, however, that very dilute sulfuric acid is commonly used in laboratories as a solvent of available soil nutrients, particularly phosphates.

Brown and Streets (24) report satisfactory and practical usage of dilute sulfuric acid in weed control. They used 2 per cent solutions for pig weed (*Amaranthus spp.*), wild mustard (*Brassica arvensis*), etc., and in increased concentrations of 5 per cent and 8 per cent for some of the hardier weeds such as sow thistle (*Sonchus oleraceus*), nettle (*Urtica gracilis*), golden rod (*Solidago sp.*), Bermuda grass (*Cynodon dactylon*), foxtail (*Setaria verticillata*) and from 10 per cent to 15 per cent for an out-and-out kill of Johnson grass (*Sorghum halepense*) and nut grass (*Cyperus rotundus*).

To avoid excessive corrosion of the metal parts of spraying equipment (they found any type satisfactory) the apparatus was coated with cylinder oil or cup grease before placing them in service.

While most investigators are inclined to favor the use of sulfuric acid weed sprays, Barbut (14) points out that one objection to this acid spray is that it is very active in deliming the soil.

Sundelin (106) found a  $3\frac{1}{2}$  per cent to 4 per cent solution of sulfuric acid, at the rate of about 100 to 135 gallons per acre, economical and effective as a control of weeds in spring cereals.

As a rule experimenters recommend that spraying with dilute sulfuric acid should take place when the crop (usually a cereal) and the weeds are both young and succulent. Blackman (20) noted diminished yields of both opal and Spratt-Archer barley when a 9.2 solution of sulfuric acid was applied in the later stages of the crop growth. However, in the third-leaf stage of Spratt-Archer barley, no damage to the crop growth nor to the malting quality of the barley was observed by the spraying of an 18.4 per cent solution of sulfuric acid. He reports a 94 to 98 per cent control of *Brassica sinapis* in clear weather, using a 9.8 per cent solution of sulfuric acid or 5 per cent solution of copper sulfate. When rain fell within 3 hours after spraying, the copper sulfate solution was ineffective but the efficiency of the acid spray was not decreased.

Few experimenters have commented on the precautions which they have taken to reduce corrosion of metal spraying apparatus when using this equipment for the application of dilute sulfuric acid. One exception noted has been Brown and Streets (24), who coat equipment with cylinder oil or cup grease before putting it in service. French and Ball (41) have made a study of equipment designed for this acid work. They recommend the use of an ejector with an ordinary spray pump to eliminate the corrosive effect of the acid on the working parts of the pump. They specify that all parts coming in contact with the acid must be of brass, but pure nickel or Monel metal, spray nozzle disks were found superior to brass. They state that a check valve should be placed in the pipe line on the suction side of the ejector.

Using this apparatus, they secured 96 per cent control of wild mustard (*Brassica arvensis*) in California barley fields using a solution of 10 per cent sulfuric acid by weight at the rate of 120 gallons per acre at a nozzle pressure of 75 pounds per square inch. The yield of barley in this experiment was increased 60 per cent.

In another publication, Ball and French (10) summarize their spraying technic as follows:

Preparation: 10 per cent by weight concentrated sulfuric acid in water solution.

Application: 130 gallons per acre.

Cost: Approximately \$3.00 per acre.

Advantages: Sprayed plots produced 50 per cent more grain than unsprayed areas.

#### *Zinc Sulfate:*

(Quotation: cryst., in barrels, \$3.30 to \$4.00 per 100 pounds)

Zinc sulfate,  $\text{ZnSO}_4$ , is a mild acid and antiseptic having properties very similar to magnesium sulfate (Epsom salts). It is prepared by roasting zinc sulfide ore in air and extracting the clinker with water.

Westveld (116) at the Michigan Agricultural Experiment Station reports that about  $\frac{1}{3}$  ounce of zinc sulfate dissolved in  $\frac{1}{2}$  pint of water, when applied to one square foot of a white spruce seedbed, proved very effective in eradicating weeds (8 grams zinc sulfate in 250 cc. water).

#### *Zinc Chlorate:*

Refer to discussion under "Sodium and Other Chlorates."

## ARSENICALS

Compounds of arsenic are used very widely and extensively in chemical weed control in the United States and in other regions throughout the world.

*Properties of White Arsenic:*

White arsenic,  $\text{As}_2\text{O}_3$ , or more correctly,  $\text{As}_4\text{O}_6$ , arsenic trioxide (arsenious oxide), is a heavy, dense-white or light-gray powder as it appears in commerce. It will dissolve to some extent in water but with difficulty because of its naturally low solubility and also because of its characteristic property of repelling water and in not readily being made "wet" by water. It is easily soluble in hydrochloric and other acids, but is brought into solution quickly by hot aqueous solutions of the alkalis. The exact chemical composition of a solution of white arsenic in aqueous sodium hydroxide is a debatable matter. Compounds having the type formula  $\text{NaAsO}_2$ ,  $\text{Na}_2\text{HAsO}_3$ ,  $\text{Na}_2\text{H}_4\text{As}_4\text{O}_{10}$ , and others may be present. It is referred to commonly as sodium arsenite solution. It may be described as an alkaline solution of arsenious oxide or white arsenic. White arsenic reacts chemically as the anhydride of arsenious acid,  $\text{H}_3\text{AsO}_3$  ( $\text{HAsO}_2$  or  $\text{H}_4\text{As}_2\text{O}_5$ ). Since it is a very weak acid, its reaction in equivalent quantities with the strong base sodium hydroxide,  $\text{NaOH}$ , forms a solution of alkaline reaction. It is possible, therefore, to prepare a highly concentrated or even saturated solution of white arsenic in aqueous sodium hydroxide and still obtain an alkaline solution.

In preparing a solution composed of white arsenic, caustic soda and water, an exothermic reaction or heat effect is produced. Within a wide range of variable amounts of these ingredients brought together, a violent evolution of heat takes place in their reaction. This property of heat evolution in the reaction of arsenic with caustic soda is made use of in preparing the so-called "self-boiling" and "self-stirring" concentrated stock solutions for dilution later as a spraying compound. White arsenic is also soluble in aqueous solutions of sodium carbonate and other mild alkaline mediums. In these cases solution is effected at a slow rate and without appreciable elevation of temperature. An alkaline solution of white arsenic may be neutralized with the addition of one of several mineral acids without precipitating the dissolved constituents. Such a solution may be rendered acidulous by adding more acid without impairing its stability.

*The Effectiveness of Arsenic as a Herbicide:*

Kennedy and Crafts (65) express the belief that arsenic is the most effective agent obtainable for general herbicidal purposes. Their criteria of herbicidal efficiency for any chemical warrant repeating. They state that effectiveness of herbicides depends, apparently, upon:

(a) Atmosphere and soil conditions which produce a water deficit in the weeds, thereby inducing a lowered pressure or suction within the plant xylem system.

(b) An exposure of the external weed surfaces to the destructive agent of sufficient duration to insure thorough absorption of the toxic solution.

Absorption of the toxic spray by the weed, they state, is probably influenced by insect injuries to the plant cuticle, by the surrounding temperature and moisture

conditions in plant and soil and by the death of cells within the plant which may render tissue more permeable.

They define the functions of the spray solution as: (a) creating a permeable entrance for the toxin to the xylem from the epidermis, and (b) as a lethal agent upon root tissue after the absorbed toxin has reached this region by translocation. Morgan (81) similarly defines the essentials for success in the use of herbicidal sprays. He states essentially: (a) that a good retention of herbicide on leaf surface is required, (b) that the spraying fluid should be capable of killing rapidly and of rendering the weed tissues permeable from cuticle to xylem, (c) that a pronounced water deficit within the xylem at the time of spraying is desirable so that extensive downward movement of herbicide will take place, and (d) that the herbicide should be highly toxic in order that the small volumes absorbed may be capable, in extremely dilute solution, of destroying a large bulk of tissue when lateral diffusion takes place.

Cost and convenience considered, dissolved arsenicals meet these requirements as well, if not better, than any chemical compound so far employed.

#### *Sodium Arsenite:*

This compound, of all the arsenicals, is used most commonly either as (a) a solution of the commercial chemical in water, (b) the so-called active constituent of spraying arsenicals prepared in the field, or (c) a dusting powder in combination with an inert carrier.

Adams (1) found a solution of 2 pounds of sodium arsenite in 52 gallons of water effective in reducing thistle (*Cirsium arvense*) and bracken (*Pteris aquilina*) in an area of one acre.

For treatment of annual weeds, Crafts (32) applied either to the top soil or to the vegetation a spray consisting of sodium arsenite solution at the rate of from 2 to 8 pounds of arsenite per square rod. He found the treatment effective.

As a treatment of wild bean (*Apios tuberosa*) in cranberry fields, Sawyer (93) describes a satisfactory experiment in which 10 pounds of sodium arsenite per acre, as an aqueous spray, completely killed the aerial portions of the wild bean.

Surber (107) reports success using commercial sodium arsenite in controlling submerged weeds in fish ponds. A very weak solution is used, it being equivalent to 2 parts per million of arsenic, or less, as  $AS_2O_3$ . He states that several applications may be needed per year and, as water hardness increases, it is necessary to increase the concentration of arsenic in the treatments. He found that natural fish foods were not impaired as a consequence.

In order to secure an efficient control of wild onion (*Allium canadense*), Woodman and Jones (120) used up to 10 per cent concentrations of sodium arsenite, arsenic acid or any one of several chlorates. Of these, they found the arsenic compounds the most efficient.

#### *Acidulated Solutions of Arsenic Compounds:*

Crafts (31) states that if alkaline solutions of sodium arsenate are acidified with sulfuric acid before application to weeds, the percentage kill is greater and, in addition, no permanent injury results in the crop-bearing power of the soil.

Robbins (91) likewise recommends an acid arsenical spray for weed control. He states that concentration of approximately 0.5 per cent  $\text{As}_2\text{O}_3$  in the acid spray are as effective against weeds as higher concentrations and that 20 pounds of arsenious oxide in this type of solution is all that is required for application to one acre of morning glory.

Morgan (80) also favors the acid arsenical spray and states that it gives very satisfactory control of hoary cress (*Lepidium draba*). He cites an interesting measurement of the translocation of the arsenical in the weed tissue 0.4 per cent  $\text{As}_2\text{O}_3$  and 5 per cent  $\text{H}_2\text{SO}_4$ , finding the rate of movement of the arsenical solution downward through the tissue of hoary cress as 0.5 inches per second under field conditions and in morning glory (*Convolvulus arvensis*) a maximum rate of 2.5 inches per second.

Crafts (31) reports that 0.5 per cent  $\text{As}_2\text{O}_3$  was the lowest concentration of arsenic in an acid spray solution which gave effective control. The corresponding concentration of acid, i.e., the most effective one, was one part of free acid to 36 parts of water (one Normal).

Carn (27) describes a method of applying the acid arsenic spray to hoary cress. He stipulates that the spray should be applied in hot, dry weather, late in the day. On the following day the treated area should be sprayed with water. The weeds should not be disturbed by cultivation for some time before spraying and after this operation the area should not be cultivated nor grazed for some 6 or 8 weeks.

#### *Comparison and Discussion of Formulae Published by Various Authors for the Preparation of the Acid Arsenical Spraying Solution:*

Normann (85) and Carn (27) specify formulae which are identical. Normann gives credit to L. W. Kephart, senior agronomist, U. S. Department of Agriculture, for the method of preparing and applying the acid arsenical solution.

##### *The Kephart-Normann-Carn formula:*

Stir the following solution until dissolved—

White arsenic — 4 parts by weight.

Caustic soda — 1 part by weight.

Water —  $2\frac{1}{2}$  parts by weight.

When required for use, add 1 part by weight of the solution to 100 parts of water. After mixing thoroughly, add 5 parts by weight of a commercial grade of sulphuric acid slowly while stirring constantly.

Robbins (91) and Crafts (31) recommend a procedure which closely parallels that given above. It follows:

##### *Robbins-Crafts formula:*

“Preparation of stock solution: Mix (dry) 4 parts by weight of white arsenic ( $\text{As}_2\text{O}_3$ ) and 1 part by weight of caustic soda ( $\text{NaOH}$ ). Add 3 parts of water and stir until dissolved.

“Preparation of spray solution: Dilute 1 part of the stock arsenic solution with 100 parts of water. Mix thoroughly and add, with constant stirring, 5 parts by weight of concentrated sulfuric acid ( $\text{H}_2\text{SO}_4$ ).”

An inspection of any of these formulae will reveal a very small quantity of water—a quantity which appears to be out of proportion with the other ingredients used. As a matter of fact, a clear, concentrated solution is not obtained in following directions outlined in either formula, but a very satisfactory *suspension* and solution of syrup-like consistency will be obtained.

Bertels and Elmanovich (15), in Russia, report their use of a spraying solution containing ten times the quantity of white arsenic (as used in the Kephart formula) for the destruction of vegetation on railroad right-of-ways. They claim that one liter of their spray solution, containing 5 per cent arsenic as  $\text{As}_2\text{O}_3$ , per square meter of roadway killed existing weeds with no recurrent growth during the remainder of the summer.

#### *Arsenic Pentoxide ( $\text{As}_2\text{O}_5$ ):*

Unlike the more common and much cheaper white arsenic,  $\text{As}_2\text{O}_3$ , this oxide of the element  $\text{As}_2\text{O}_5$  (also white) is readily and freely soluble in water, acids, alkalis and other solvents.

In spite of its higher cost, arsenic pentoxide has been used to a large extent in experimental weed control. It should be mentioned, however, that in addition to the increased expense involved in making field-scale use of arsenic pentoxide, there is a good reason to question its general effectiveness as compared to common white arsenic.

Brenchley (23), in her text on plant poisons, states that the toxic effect of arsenic on the higher plants (weeds) is more marked with arsenious acid and its compounds (white arsenic is an example) than with arsenic acid and its derivatives, of which arsenic pentoxide is an example. Nevertheless, arsenic pentoxide has its supporters. Woodman (119) found that a 1.5 per cent solution of arsenic pentoxide (one pound  $\text{As}_2\text{O}_5$  dissolved in 8 gallons of water), applied at the rate of 240 gallons per acre, controlled all weeds except yarrow (*Achillea millefolium*), dandelion (*Taraxacum officinale*), dock (*Rumex sp.*) and a sorrel (*Oxalis sp.*) as effectively as the same volume of a 2½ per cent solution of sodium chlorate.

Morgan (81) also secured very satisfactory results with arsenic pentoxide in the control of hoary cress (*Lepidium draba*). In a field trial he sprayed the weeds with a 6 per cent solution of the chemical dissolved in water. Control was 93 per cent for the period of a year after treatment. His most satisfactory procedure consisted of an application of spray which contained a total of nearly 100 pounds of the pentoxide. He noted a decrease in the efficiency of the spray with an increase of rainy weather during the week before application was made. On the other hand, sunlight, high air temperatures and low humidity—factors which hastened drying out of the weeds and soil—increased the effectiveness of the treatment.

From New Zealand, Levy and Madden (70) report the pentoxide as an excellent contact herbicide for application to weeds on lawns. They comment on its ready solubility in water and state that it shows satisfactory differentiation in attacking weeds rather than grasses in lawns. They believe that when absorbed by the soil the pentoxide reverts rapidly to a non-injurious form and thereby permits early renewed growth of the established turf.

In comparing experimental trials of arsenic pentoxide and sodium chlorate, they show that chlorates tend to make the soil alkaline—an undesirable occurrence for lawns—and favor undue return of clover (*Trifolium sp.*) growth. The recovery of the lawn to a favorable green stand is less rapid following chlorate treatment as contrasted with the arsenic pentoxide applications.

In parts of Hawaii, cactus (*Opuntia megacantha*) is a common nuisance. Its eradication by spraying with chlorate solutions has met with fair success. van der Merwe (112) describes an effective method of eradicating this pest in South Africa. Young growth of prickly pear (*Opuntia megacantha*) is killed by spraying it with a solution of arsenic pentoxide, 3 pounds dissolved in one gallon of water—a solution containing about 30 per cent arsenic pentoxide. In older or more mature plants, application is made of the same concentration of the pentoxide but dissolved in concentrated sulfuric acid. Jointed cactus (*Opuntia sp.*) also yields to this treatment but only the portion above ground is destroyed.

#### *The Fixation, Toxicity and Stimulation to Plant Growth of Arsenic Applied to the Soil:*

In soils containing 20 per cent, more or less, of an iron oxide colloidal clay-like fraction, soluble compounds of arsenic are fixed at a rapid rate.

Other factors of significance regarding the soil fixation of applied arsenicals are the wide diffusion, comparatively small amounts per application and the infrequent treatments of the chemical, per crop, which are made. In short, the soil receives a very light "dressing" of the chemical a few times per crop cycle (one year to 20 months) distributed upon weed surfaces in an extremely fine state of particle division. One would expect to find, therefore, an intensive soil fixation of this applied arsenic.

Crafts (34) found the toxicity of sodium arsenite greatest in Fresno sandy loam and lowest in Yolo clay loam. The loss of toxicity with time and cropping was greatest in the Yolo soil and least in the Fresno type. Stockton and Columbia soils "held" twice as much arsenic as the Fresno soil. Amounts of arsenic "held" by all four soils was greater with increased concentrations of solutions. Even after he leached the Yolo soil with 160 surface cm. of water, the upper 4 inches of soil was "sterile." The chemical (arsenic) had not gone down below the 16-inch level. Similar leaching removed all the arsenic from the Fresno soil.

Zuccari (123) made a study in Europe of the normal occurrence of arsenic in soils. His findings have a bearing on the phenomenon of soil arsenic fixation.

In a study of 20 soil samples, varying in physical and chemical composition and taken from different depths in different geological formations and varying elevations, Zuccari found the arsenic content to vary from about 5 to 150 p.p.m. of  $\text{As}_2\text{O}_3$  (calculated by the author).

#### *Discussion on the Toxicity of Arsenic in Soil to Vegetative Growth, as Compiled From the Literature:*

Gray (44) states that a heavy dressing of sodium arsenite upon bindweed (*Convolvulus arvensis*) on a California soil destroyed 85 to 90 per cent of the weed but did not eliminate it and further, the land remained *barren* for at least 14 months thereafter.



Morris and Swingle (82) state that apart from its poisonous properties, arsenite of soda tends to change for the worse the mechanical condition of the soil and that it is strongly "held" in the soil and is not easily washed out by heavy rains. They state that if it is used too freely the soil may be poisoned for subsequent crops. They observed that beans and cucumbers were very susceptible to arsenic in the soil, whereas cereals and grasses proved more resistant.

Safety in use of calcium arsenate for treatment of cotton as a control of boll weevil appears to depend upon the amount of iron hydroxide in the soil which supports the cotton plant. Paden (87), in studying the differential growth response of cotton and cowpea plants on certain soil types to which varying amounts of calcium arsenate were added has found that dark-colored soils and fine-textured soils may be more tolerant than either light-colored or heavy-textured soils. Cooper, Paden, et al (30), in commenting on their researches in South Carolina, state:

It has been observed that these soil types vary markedly in their response to additions of calcium arsenate. The coarse-textured gray sandy soils . . . are seriously affected by a relatively light application of calcium arsenate, whereas the fine-textured dark-colored soils . . . are not seriously affected by applications of calcium arsenate which would be commonly used in combating the cotton boll weevil.

Many research studies on the relations of soil arsenic to plant growth reveal definite evidences of stimulation to vegetation where low concentrations of arsenic are present. Others indicate an unusually high degree of tolerance by certain plants to quite large quantities of arsenic in the soil. Still others suggest that, on the whole, arsenic additions to the soil may be beneficial rather than harmful to a large group of plants—particularly cereals and grasses (and, apparently, to sugar cane).

Results of studies supporting contrary conclusions, and, in part, those which uphold beneficial influences of arsenic upon certain crops have been cited.

John Stewart (100), for example, in an experiment, grew wheat and beans in soil and treated them, in steps, with 0 to 500 parts of soluble arsenic to one million parts of dry soil (using disodium arsenite). Stimulation in growth was observed (as compared to controls) in pots containing from 25 to 75 p.p.m. of arsenic. Checking of growth occurred in higher concentrations and death to the plants was observed in the highest concentrations. Dry weights of these plants did *not* give evidence of having been increased by arsenic in lower or stimulating concentration ranges. They did show, however, a decrease with the highest concentrations, where checking of growth or death occurred.

Granted that arsenic in low concentrations in the soil does stimulate the growth of certain higher plants, ". . . what are we to use as a criterion of such stimulation?" question Stewart and Smith (101). Quoting from their discussion:

If stimulation occurs will the dry weight of the plant necessarily be greater than it otherwise would have been? Is not a healthy, vigorous appearance also evidence of beneficial influence? The life processes of a healthy looking plant may proceed more rapidly than those of a plant of less vigorous appearance, and the former may arrive at maturity at a somewhat earlier date than the latter without attaining a greater weight.

Pot experiments with radishes show that when grown in soils of low arsenic content they had thick, fleshy, fine-looking roots, while those grown in high arsenic soils were longer and of smaller diameter. In this case, the arsenic had a stimulat-

ing influence up to and including a concentration of 250 parts of arsenic per million of soil. A great variability to resistance or to stimulation by arsenic to various plants has been found.

Continuing quotations from Stewart and Smith :

The amount of arsenic absorbed by the plant which is necessary for the checking of growth seems to have been, in parts per million of dry plant matter, 50 for beans, 78 for potatoes, 52 for wheat, 193 for peas, and 940 for radishes. When the plant is killed the **smallest** amount of arsenic absorbed was shown to be 269 parts per million for wheat, 524 for potatoes, 678 for beans, 1190 for peas. . . .''

The authors question :

Is the fine, healthy appearance of plants grown in the presence of small quantities of arsenic compounds due to the destruction, by the arsenic, of soil microorganisms which are injurious to the higher plants or is it due to a direct action of the arsenic compound on the higher plant? [Water culture experiments indicate that the beneficial effect] . . . is due to a direct chemical-physical action. But both kinds of action may be involved. The problem is interesting and awaiting solution.

[Poisoning by arsenic to plants] . . . is probably due to a chemical action on the chlorophyll in which the arsenic is involved. [If it] . . . were due in the main to injury to the root or tissues of the stem, its visible effects should be seen first at the top of the plant and extreme tips of the leaves, which is exactly the opposite of what is actually observed.

[Twenty-five to seventy-five parts of arsenic per million of soil appears to be generally the range of stimulating influence.] In the case of the radish, however, this visible result [stimulation] appears in the underground part and not in the foliage.

It would, therefore, seem that the accumulation of arsenic in the soil, as a result of the spraying . . . if not continued to excess, may be beneficial rather than injurious.

It has been shown by several investigators that fungi exist which utilize compounds of arsenic in their development and multiplication. Accumulation of arsenic in the soil under conditions of water logging, i.e., reducing conditions, favor fungi utilization of the element in which it is converted to arsine,  $\text{AsH}_3$ , a gas which escapes to the atmosphere.

Reed and Sturgis (90) comment on this reduction of soil accumulation of arsenic. They also point out the marked effect of soil type upon the toxicity of the arsenic it may contain. They found that a soil extraction with 0.05 N hydrochloric acid brought into solution that fraction of its arsenic content which was related directly to the degree of toxicity to plant life shown by that soil. This method of analysis to determine soluble or toxic arsenic has been used by other workers. Reed and Sturgis state :

Arsenicals used in the dusting of cotton have had a toxic effect on succeeding crops of irrigated rice in certain soils of the Southwest.

The effect on the yield of rice of applications of varying amounts of calcium arsenate on different soil types was studied and it was found that the toxic effect was governed largely by the soil type. Rice on the lighter soils was seriously affected by applications of 50 pounds per acre of calcium arsenate, while on the heavier soils 150 pounds per acre were not injurious. No correlation could be found between water-soluble arsenic and toxicity, though a *relationship existed between 0.05 N HCl-soluble arsenic and toxicity.* (Italics ours.)

Less total arsenic was found in the soil at the conclusion of the test than was present at the beginning. An analysis of the rice heads and straw showed that the loss could not be accounted for by crop removal. The soil was found to be in a highly reducing condition when flooded under cultivation, and it is suggested that this loss in arsenic content might be accounted for by com-

plete reduction to gaseous arsine. Furthermore, the evidence seems to indicate rather conclusively that it is the reduced arsenic compounds, arsenites, etc., that are particularly toxic to rice under flooded conditions.

The relationship of the iron hydroxide and iron oxide colloids of the soil to fixation of arsenic and to the rendering of the element less toxic to plant growth by its ferrous absorption is proven very clearly by the researches of Albert (2) in South Carolina. He writes:

The results of previous years had shown that additions of ferrous sulphate to arsenic-toxic soils had benefited subsequent crop growth and that red clay soils relatively high in iron compounds had a much greater capacity to render arsenates non-toxic than did the gray, sandy soils low in iron. Since many of the iron compounds in the soil are forms of iron oxide in different degrees of hydration, the power of iron hydroxide to absorb arsenates was studied.

Iron hydroxide precipitates were prepared according to a standard method. The carefully washed precipitates were put into a relatively large amount of water, to which known amounts of sodium arsenate were added. This mixture was then well shaken and allowed to stand for some hours. It was found that the arsenic up to 0.6 per cent by weight of the ferric hydroxide was completely removed from the solution. Larger amounts of arsenic were not completely removed from solution.

Precipitates of aluminum hydroxide were prepared by a standardized method and their power to absorb arsenic from solution studied. It was found that aluminum hydroxide was not nearly as active as iron hydroxide, only small amounts of arsenic being absorbed.

These laboratory results indicate that the superior arsenic-fixing power of red clay soils, as compared to gray sandy soils, is related to the greater supply of iron-containing colloids present in such soils.

Mixtures of red clay subsoil with an arsenic-toxic gray sandy topsoil were made to learn if the arsenic would be removed. Determinations of arsenic in collodion bag diffusates gave the following results:

Topsoil	Red clay	Soluble arsenic
100%	0	0.4 p.p.m.
90%	10%	0.1 p.p.m.
80%	20%	slight trace
50%	50%	none
0	100%	none

These results indicate that a mixture of about 20 per cent red clay subsoil into a topsoil high in arsenic will preclude practically any arsenic from going into solution in the soil.

Cowpeas were planted in 2-gallon earthenware jars containing mixtures of red clay and high arsenic topsoil in order to test these results on plant growth. [The figure] . . . shows the growth made by cowpeas in a jar containing a high arsenic topsoil to which had been added 10 per cent by weight of a red clay subsoil and calcium arsenate at the rate of 100 pounds per acre. The other jar had the same treatment except for the addition of the red clay. The cowpeas in the latter jar made no growth and eventually died, whereas the plants in the jar containing the red clay produced a vigorous growth. Jars containing larger percentages of clay showed no improvement over the jars containing 10 per cent.

These results suggest the possibility of correcting arsenic toxicity by methods of tillage which will incorporate red clay subsoil into topsoil.

Greaves (45) studied the effect of arsenic upon ammonification and nitrification in soil. He found that all compounds showed stimulation in lower concentrations and toxic action in the higher. It was concluded that water-soluble arsenic may exist in such soils to the extent of 82 p.p.m. without entirely stopping ammonification and nitrification.

Additions of arsenic to soil appear to set phosphates free from the fixation soil complex and permit plant life to utilize these phosphates which otherwise may be difficultly available.

Greaves (45) concurs in this belief. He states that arsenic cannot replace phosphates in vital processes of nitrogen-fixing organisms but it can in some manner liberate the phosphoric acid from its insoluble compounds. This may be a direct or an indirect action. Arsenic stimulates the cellulose ferments and these in turn react upon the activity of the nitrogen-fixing organisms. The nitrogen-fixing powers of soil extract, of filtered soil extract and soil dried for some time are only slightly stimulated by arsenic, showing that arsenic acts mainly by the removal of a thermolabile body which occurs in the soil.

In another article Greaves (47) points out that arsenic by various means stimulates the bacterial activity of soil which results in greater crop yields. This increased growth must be looked upon as due to a stimulant and not to the direct nutritive value of the substance added. Soils so treated would wear out more quickly and produce larger crops than would soils not so treated. *It is important to know that arsenic has to be applied to a soil in enormous quantities before it retards microscopic plant life and most likely before it retards the growth of higher plants.* Other experiments have demonstrated that the addition of arsenic to a soil causes the liberation of the insoluble plant foods of the soil, especially the phosphoric acid.

In a further study of the effect of arsenic upon soil nitrification Greaves and Anderson (49) found that in a given soil Paris green was toxic at 120 p.p.m. and that sodium arsenate was toxic at 40 p.p.m. and that with the arsenate at 250 p.p.m., nitrogen fixation by bacteria was entirely stopped.

Later, Greaves (47) found that the nitrogen-fixing powers of soil were greatly increased when arsenic was applied. Soils high in organic matter fixed as much nitrogen in the presence of arsenic and in the absence of mannite (a sugar) as they did in the presence of mannite and the absence of arsenic. He found the stimulation greatest when the water-soluble content of the soil was at about 10 p.p.m. "This quantity exceeds that found in most soils so it is likely that arsenic will stimulate in place of retard bacterial activity of the soil."

Jadin and Astruc (60) make this statement: "Arsenic and manganese are of the greatest importance in the vegetable cell, the former exerting an influence comparable to phosphorus, the second favoring the oxygen reactions in the plant."

Commenting on the relationship of arsenic and phosphorus in the soil in reference to plant growth Stocklasa (103) points out that while arsenic cannot replace phosphorus in the living cell, it is able to induce the formation of furfural derivatives and consequently increase the development of the organ of assimilation in the plant.

Picado (88) credits arsenic with having the properties of a catalytic soil fertilizer. He found, in small applications, that arsenic had a tendency to enhance the yield of corn fodder. A progressive increase in the application of arsenic indicated that it had no effect on crop yields in amounts greater than 7.32 pounds per acre. In such small quantities arsenic apparently did not act as a sterilizing agent. In sterile soil *and* in natural soil, small applications of arsenic increased the yield of

corn. The conclusion was reached that arsenic used in this manner acts as a catalyst (stimulates plant metabolism and accelerates advantageous soil reactions).

The results obtained by many research workers, therefore, indicate that arsenic in small concentrations in the soil solution on lands containing colloidal iron oxide is not harmful but actually may be of benefit. Also that to be toxic to higher plants it must be present in high concentrations in the soluble form.

Greaves (48) concludes a discussion on the subject with this statement :

The study of arsenic-decomposing fungi by Thom and Raper and their claim that the fungi will keep down the concentration of arsenic in the soil gives to the subject a brighter outlook, for if arsenic does not accumulate in soil the likelihood of injury is slight. Moreover, *the quantity of arsenic in the soil does not determine its toxicity, but rather its toxicity is determined by its solubility, which is dependent upon the chemical and biological properties of the soil.* (Italics ours.)

### *Toxicity of Arsenic to Animals:*

Arsenic is employed largely by veterinarians as a tonic and reconditioner. Its use in this regard is common throughout the world. As in the case of plant life, small doses of arsenic appear to have at least a temporary beneficial effect on indisposed animals. Larger doses are frequently fatal to cattle or mules even though the amount imbibed may be 40 grains or less.

The discussion which follows refers principally to the poisoning of animals which may have grazed upon arsenic-treated weeds or grasses.

Husband and Duguid (58) found that cattle which received more than 30 grains of white arsenic in one dose, by mouth, eventually died from the effect. When given 20 grains they all survived. Thirty grains caused death in 86 hours, 56 grains in 73 hours and 112 grains in 40 hours. When confined to areas which had been sprayed with 1½ pounds of sodium arsenite per acre, cattle ate sufficient of the grass to be poisoned.

Cattle, other animals, and men develop a degree of immunity to the toxic effects of arsenic when this substance is administered regularly, first in small doses and thereafter in progressively larger ones. Besredka (16) induced immunity to the toxic effects of arsenic upon the skin of rabbits by repeated applications of the chemical in an ointment to a preselected area on a partially shaved animal. Immunity was confined to the treated area of the skin, but no anti-body was produced by the animal.

Woodman and Wiley (121) have found that the addition of certain coal tar derivatives as an emulsion to an arsenical spray solution increases the toxic effect upon treated weeds and imparts such an unpleasant taste to them that animals will not eat them. Cresols may be selected as the coal tar preparation and glue may be employed to emulsify the mixture.

As an illustration of the harmless effects of arsenic when taken by animals in small quantities over an extended period of time, Frederick (40) reports that alfalfa hay, when dusted with 3 to 6 pounds of calcium arsenate per acre and fed to cattle, horses, and sheep for 40 days, with no other food except water and salt, showed no noticeable injurious effects to this livestock.

When dusted with 2 pounds of calcium arsenate per acre (common practice for controlling alfalfa weevil), alfalfa, so treated, may be fed freely to livestock for a

whole feeding season without harming them. He added that where arsenic-treated alfalfa hay was fed the animals, more water was consumed by them, but not as much hay. Apparently the arsenic in the treated hay, he states, acted as a stimulant or tonic for the animals. (This statement does not appear to be logical. The author's understanding of the effect of a stimulant or tonic is to *increase* consumption and utilization of food to the general betterment of the animal.)

When rabbits succumbed after receiving repeated poisonous potions of arsenic, Schonberg (94) found that the ingested arsenic appeared in the liver, kidneys, brain, skin, and fur of the dead animals.

Johnson (63) recommends that arsenic trichloride be employed for weed destruction because its taste is repulsive to animals and they avoid it. He states that the arsenite compounds ordinarily used upon sprayed vegetation are attractive to grazing animals and is so toxic that a few mouthfuls may cause death.

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## The Prebaited Feeding-Station Method of Rat Control

By R. E. DOTY

### INTRODUCTION

Every control method or plan for poisoning field rats that has shown a reasonable efficacy when first tried has dropped in effectiveness with time. While this may be partially due to a gradually developed indifference on our part with a cessation of the active control measures, the factor of prime importance is the uncanny ability of the group of surviving rats to circumvent the plan and quickly repopulate the area.

In the past, rat control in Hawaii has been based chiefly on the use of poisoned grain wrapped as torpedoes; more recently the Bureau of Biological Survey, United States Department of Agriculture, has used meat pellets or sausages. These methods were highly developed through extensive and painstaking trials by many workers, yet in some cases serious difficulties still remain which prevent satisfactory control.

Heavy losses from molds occur when torpedoes are distributed in fields receiving a heavy rainfall. It is very difficult to make a waterproof package without reducing its attractiveness to rats. All good baits spoil easily when exposed in the open fields. Ants and cockroaches eat holes in the covering of the torpedoes, thus allowing moisture to enter and spoil the bait very quickly. On any large-scale operation it is impossible to determine how many torpedoes are being eaten. Hence a liberal number of torpedoes are generally distributed in order to insure enough for the entire population. The result is that large numbers remain in the field to spoil in a few days, and it is common experience to find plenty of moldy torpedoes along the routes of earlier distributions. Moreover, some of the large-sized torpedoes that were formerly used contained such low concentrations of poison that they could not be effective unless eaten in quantity. These conditions have been noted at the Kauai Variety station and elsewhere. The most serious problem of all in the use of poisoned bait is the fact that only a small proportion of the torpedoes are entirely eaten, while many more are partially eaten or only nibbled.

From many personal observations, it is our belief that, with ample natural food present in a cane field, many rats are suspicious of any newly discovered food supply and only nibble at or entirely refuse to eat it for 2 or 3 days; even though it is of the best non-poisonous material. Thus it is not so much a case of their detecting the poison in the poisoned bait as it is their general suspicion of any new food supply. If this is the actual situation, poisoned bait placed directly in the field very frequently is merely sampled. Large numbers of rats, then, do not get a lethal dose the first time they nibble a torpedo, and the resulting discomfort renders them definitely bait-shy. Perhaps they warn others of the danger also. These defects have recently been partially overcome by increasing the concentration of the poison, so that a much smaller portion of bait would carry a lethal dose. Garlough and Spencer (6), of the Biological Survey, have increased the poison ratio to as high as 1 part in 64.

The present paper presents and discusses a different plan of attack which promises to be a valuable aid in practical field-rat control. Details of all experiments herein discussed are recorded under Project A-108 in the files of the Experiment Station.

#### PLAN

The plan consists in feeding field rats unpoisoned grain which has been placed in containers under a cover and exposed for several days (6 days or more), until a large part of the surrounding rat population has discovered the new source of food and has formed the habit of visiting these specific feeding places. If it is true that "in every tribe there is an official taster"\* who samples the new food first, then the six days during which unpoisoned grain is exposed would be sufficient to insure success for the plan. After the rats have acquired the habit of visiting these stations regularly and have gained confidence in the food, the operator removes the unpoisoned grain from these feeding stations and substitutes poisoned grain in its place. Owing to the familiar surroundings and the apparently identical food, the rats will return the following night to eat a lethal dose without suspecting the deception. It is advisable to make the substitution over a large area on the same day so that there will be the fewest possible unpoisoned rats able to observe the plight of their companions and perhaps become educated to the deception. Even the best-educated rat cannot predict when the change from unpoisoned to poisoned bait will be made on a subsequent campaign as this depends on such circumstances as weather and the whims of the operator. This plan should be effective, even following recent direct poisoning with torpedoes, irrespective of the bait used, but rolled oats stand out as the most efficient bait at present. Owing to the large quantity of oats being consumed at the time poison is administered, high concentrations of the poison are not necessary because the rats are eating freely, instead of nibbling to sample the food as formerly.

The method of prebaiting using covered feeding stations has advantages over direct poisoning with torpedoes. At the beginning of the field experiments in prebaiting, it was believed that the additional labor necessitated by the extra visits to the field would make the method unduly expensive, but after a demonstration, it was found to be practically balanced by the elimination of the expense of wrapping each individual torpedo by hand.

There should be less waste from spoilage of grain under this plan. If reasonable care is taken to keep the grain dry as it is placed in the pans under the iron covers, it should keep at least 4 days even during very wet weather. This is long enough for the rats to find the stations and any station that has not been visited in that time should not be baited with the expensive poisoned grain. Intelligent placing of the poisoned oats, based on knowledge of previous unpoisoned oats consumption, should cut the spoilage of the expensive poisoned oats to a minimum. Most of the poisoned grain eaten at the active stations is consumed on the first and second nights, while it is still fresh, with little or no acceptance after that time. Only the surplus grain would be left to spoil. Unpoisoned oats cost approximately 4½ cents per pound while the value of the poisoned oats is from 13 to 17 cents per pound.

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\* Henry Morton Robinson, "Pied Pipers, Inc.," Review of Reviews, March 1937.

By keeping some records of consumption, this plan also offers a practical means of determining the relative density of the rat population in a specific area without resorting to expensive trapping trials. In all tests with prebaiting, it was noted that there was no (or very little) consumption of grain for the first few days, but in less than a week a large clientele had been built up. The progressive increase in consumption remains the most vital factor in the success of the plan; without this increase there would be little or no advantage over direct poisoning.

The idea of prebaiting animals is not new. The Biological Survey has used prebaiting for coyotes on the mainland. Referring to rats, Silver (9, p. 7) states that "In stubborn cases, or when one is willing to go to additional trouble to increase the chances of success, prebaiting is recommended. This consists of exposing fresh, unpoisoned baits, prepared precisely as the poisoned baits will be later on except for omitting the poison. If these are taken freely the first night, poisoned baits should be substituted after an interval of one or two nights. Otherwise clean baits should be exposed at two or three day intervals (picked up in each case the following morning), until any suspicion the rats may have has been overcome and they take the baits without hesitation. When this occurs, they will doubtless take the poisoned bait the next night, and then the result should be a complete clean-up of the infestation."

Prebaiting of rats on a field scale in Hawaii is the result of experimentation since April 1935, following C. E. Pemberton's suggestion that some form of prebaiting should be studied along with our torpedo work. The idea of trying to make this plan of practical use began at the Manoa substation when various grains were placed in open tins under box covers to allow the rats to express their preference in grains.\* The rats returned each night in such increasing numbers that liberal quantities of the popular foods were required to keep the tins filled. After trying other tests using unpoisoned grains with various oil attractants, poison was applied to these feeding places with very effective results. Other tests of food preference and poisoning were continued at intervals until March 1936. Poisoning of rats by feeding under shelters was discontinued at the Manoa substation in April 1936, following the unfortunate poisoning of three dogs that ate the rolled oat briquettes (Experiment No. 25), and after some delay a small area at the Kailua substation was used in testing types of wood and metal containers (Experiment No. 27). The square tin pans with galvanized iron covers proved the most practical and a supply was made up for further study. Another test was conducted at Kailua in August 1936 (Experiment No. 28), followed by one at Waipio in January 1937 (Experiment No. 31). At this same time, in response to a request by George Y. Bennett, manager of the Waimanalo Sugar Company, a larger test (Experiment No. 30), was carried out on that plantation.

R. L. Walker, agriculturist at Kaeleku Sugar Company, who had collaborated in the Manoa experiments, fabricated some boxwood shelters and placed them in the field. Loose unpoisoned barley was put in these shelters for from 4 to 8 days followed by poisoned barley. Mr. Walker's report to Manager J. F. Ramsay, of Kaeleku Sugar Company, dated May 19, 1936, states "These tests show that this

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\* The favorite was (1) sunflower seed, followed in order by (2) rolled oats, (3) rolled barley, (4) cornmeal, (5) cracked corn, (6) wholewheat, and (7) milo maize.

method can be used successfully to feed poisoned bait to rats with comparatively little waste. The only noteworthy objection to this method that occurs to the writer is the awkwardness which the transportation of any considerable number of these hoppers would involve if they were placed in locations at a distance from an auto road."

During April and May, 1937, two field tests were conducted, one at Kilauea Sugar Plantation Company and the other at Grove Farm Company. With the co-operation of the managements these tests were operated on a sufficiently large scale (90 and 143 acres respectively) to make the results significant. Three other minor experiments were conducted at Kilauea Sugar Plantation Company at the same time. In July 1937, an experiment to demonstrate the value of sweetening the poison formula was conducted at the Pepeekeo Sugar Company and at the Hilo Variety station.

Each successive test gave additional or confirmatory information and various changes and refinements were introduced as the work progressed. The findings to date show that this plan of poisoning rats may be applied to most field conditions with satisfactory results.

#### EQUIPMENT

A simple and inexpensive feeding station as developed at present consists of a small, tinned baking pan 7 by 7 by 1¼ inches placed under a curved cover, shaped like the tops of the old covered wagons, made of a 15- by 16-inch piece of light (28-gauge) galvanized iron. To curve the covers into a half cylinder they may be shaped over a piece of 6- or 7-inch pipe or by a tinsmith's roll-forming machine. The square, almost vertical-sided baking pans are preferable to the round sloping-sided pie pans, as their use practically eliminates the spilling and consequent wasting of the grain. For convenience in keeping records of the stations, each cover should be numbered before bending, using a good waterproof paint. Ordinary lettering lampblack will smear, especially after the covers have been freshly treated with raw linseed oil. With exposure to the weather, the covers lose their shine and soon blend into the landscape. It may be advisable to paint a yellow or white stripe along the top to increase their visibility.

Both the pans and covers nest together in compact form, making for convenience in distribution through the fields. One man can carry at one time the complete equipment for 20 stations (see Figs. 1 and 2). This consists of 20 pans weighing 6 pounds, 20 covers weighing 26 pounds, and at least 5 pounds of grain in a burlap or preferably a waterproofed canvas bag slung over the shoulder. The covers may be carried under the arm or on the shoulder while the pans may be carried in the other hand or in the bag with the grain. It is recommended that raw linseed oil as an attractant be rubbed on the inside of the covers before they are taken to the field. The approximate cost per station based on Honolulu prices is about 18 cents; 11 cents for the cover, including cutting, and 7 cents for the pan. A sheet of 28-gauge iron, 30 by 96 inches costing about \$1.07 will cut into twelve 15- by 16-inch pieces.

It has been recommended that stations be placed four to the acre. Allowing an interval of three months between poisoning campaigns in any given area with the stations in place 10 days, 45 stations costing about \$8.00 for permanent equipment will serve 100 acres. For a 2-month interval 70 stations are necessary.



Fig. 1. Materials for twenty feeding stations ready for distribution in the field. Twenty covers carried under the arm (weight twenty-six pounds); twenty pans carried in the other hand or in the bag (weight six pounds); and five pounds of grain carried in the bag.





Fig. 2. Same materials as shown in Fig. 1 showing covers placed on the shoulder as an alternate carrying position.



Fig. 3. Filling the pan with rolled oats. One cupfull (one-quarter pound) is a convenient amount of unpoisoned grain.



Fig. 4. Inserting the pan under the cover.

## BAIT

The experimental work with prebaited feeding stations has been done with a good quality of bulk *rolled* (not crushed) oats. A good grade of rolled barley would serve as a substitute but is wasteful because the hulls, which the rats invariably leave, will retain an appreciable amount of poison. Rolled grains have distinct advantages over whole kernels, in being more attractive to the rats and a better absorbent of the poison solution.

Under extremely wet conditions, rolled oats, placed in stations surrounded by dense weed growth where there is poor circulation of air, will mold from condensation of moisture in 3 to 4 days. Some loss will occur from this cause in the less active stations, during periods of high humidity and frequent rains. Spencer (7), of the Biological Survey, has reported some benefit from the use of sodium sulphite in rat bait as a protection against spoilage. Grove Farm Company is now testing rolled oats containing one per cent sodium sulphite as a mold deterrent in field trials. A preliminary test conducted several years ago with sodium benzoate proved unsuccessful.

Many poisons have been used in rat control, and of these the most efficient to date has been thallium sulphate which was used exclusively in these tests in concentrations varying from 1 to 250 to as high as 1 to 100. The poisoned oats used in the Kilauea Sugar Plantation Company and Grove Farm Company experiments, as well as two small early experiments at the Kailua substation, all carried thallium sulphate at the rate of 1 pound to 250 pounds of oats. At Waipio substation and at the Waimanalo Sugar Company the poison used was much stronger (1-100). While a smaller quantity of poisoned oats is needed for a lethal dose in the 1-100 formula, the abrupt drop in consumption often noted on the first night of poison may indicate some detection of the change. In a small test at the old Manoa substation (Experiment No. 25), the rats showed little preference between poisoned and unpoisoned briquettes on the first night of the poison exposure, but after the third night the surviving rats showed a decided preference for the unpoisoned grain; the consumption of unpoisoned oats increased while the poisoned oats remained practically untouched. From this it appears that rats are readily educated to detect poisoned material even though thallium is recognized as being both odorless and tasteless. In a test at the Waimanalo Sugar Company (Experiment No. 24) comparing poisoned and unpoisoned rolled barley and rolled oats in adjacent pans, the rats ate 10 per cent less barley and 27 per cent less rolled oats from the poisoned pans than they did from the unpoisoned pans.

The minimum lethal dose (M.L.D.) of thallium sulphate has been studied by several investigators. Munch (8, p. 20) reported that "the minimum lethal dose . . . was found to be . . . 31 milligrams of thallium sulphate per kilo, [of body weight] when fed to rats." Recent studies by Garlough and Spencer (6) indicated 30 milligrams to be lethal. This disregards any possible neutralizing action of food acids.

To better visualize what this means in practical terms, the following tabulation of theoretical killing power of the various concentrations of poisoned rolled oats has been prepared.

TABLE I

THEORETICAL EFFICIENCY OF THALLIUM SULPHATE EXPRESSED  
IN WEIGHT OF RATS KILLED

Concentration of thallium sulphate	1-64	1-100	1-150	1-200	1-250	1-666*
Milligrams of thallium sulphate						
per pound of oats.....	7087	4536	3024	2268	1814	681
Weight of rat that should be { (kilos)	236	151	101	76	61	23
killed per pound of oats { (pounds)	520	333	222	166	133	50

\* This was the accepted concentration formerly used in torpedoes.

These weights are calculated on the basis of 30 milligrams of thallium sulphate as a lethal dose for 1000 grams of body weight of rats.

*Example:* Taking the 1-100 concentration we have:

$$1 \text{ lb. oats contains } \frac{4536 \text{ mg. thallium}}{30 \text{ mg. (M.L.D.)}} = 151.2 \text{ kgs. or } 332.6 \text{ lbs. of rats.}$$

This is equivalent to approximately 450 adult *Rattus norvegicus* (Erxleben) or 2,000 *Rattus hawaiiensis* (Stone). (The average weight of an adult *norvegicus* is approximately 325 grams, and of the little *hawaiiensis* 60 grams.)

TABLE II

WEIGHT OF RAT KILLED BY 1, 2 AND 3 GRAMS OF POISONED OATS  
AT THE VARIOUS CONCENTRATIONS

Concentration of thallium sulphate	1-64	1-100	1-150	1-200	1-250	1-666*
1 gm. oats should kill.....(pounds)	1.1	.7	.5	.4	.3	.1
2 gms. oats should kill.....(pounds)	2.3	1.5	1.0	.7	.6	.2
3 gms. oats should kill.....(pounds)	3.4	2.2	1.5	1.1	.9	.3

\* This was the accepted concentration formerly used in torpedoes.

The last column of Table II shows that three grams of grain of the old 1-666 formula would kill only a small half-grown rat weighing .3 pound. Some old formulas were even weaker (1-1000) and proportionately more bait was required to kill. Under normal field conditions there are other foods available and there is little doubt but that many rats were satisfied before a lethal dose had been eaten. Thallium salts applied externally are strongly depilatory and sub-lethal doses of these salts taken internally have the same property of causing the hair to fall out. Hairless or partially hairless rats were reported during this period of low bait concentration. These individuals which had taken the poison in quantities insufficient to kill were in all probability bait-shy thereafter.

Again referring to Table II, we note that 2½ grams of oats of 1-250 concentration will kill a large rat weighing three-quarters of a pound, which is about the average for an adult Norway rat, *Rattus norvegicus* (Erxleben), the common field rat on Kauai. If the concentration is increased to 1-200 only 2 grams of oats are required to kill a rat of the same size. If the concentration of thallium is further increased to 1-100 only one gram is required. For all practical purposes a concentration of 1-200 should be sufficient for the prebaited feeding-station method when the rats have developed the habit of eating freely, as under these conditions the rats eat much more than the minimum lethal dose. It is recommended that the concentration of poison in rolled oats be not less than 1-250. If barley is used, this mini-

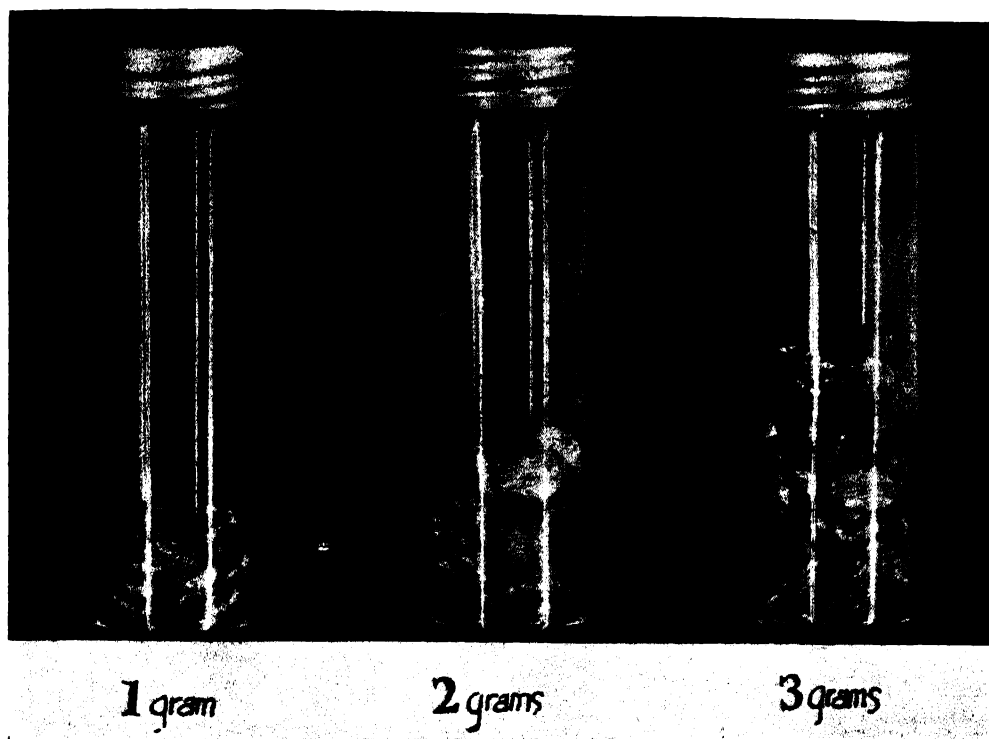


Fig. 5. An idea of the amount of rolled oats represented by one, two, and three grams (actual size). The weight of rat killed by these amounts of poisoned oats is shown in Table II.

mum concentration should be not less than 1-200, due to the loss of poison on the hulls.

While it cannot be stated exactly what the average consumption of oats by a large rat may be under field conditions where natural food abounds, it is probably between 3 and 5 grams at a time. Thus, taking 3 grams of 1-200 poisoned oats as an average consumption in the field, one pound of this material should account for 151 rats. If the average consumption should reach 4 grams each, one pound of poisoned oats will still be sufficient to kill 113 full-sized rats. On the above assumption, increasing the concentration of thallium merely gives an overdose—a margin of safety or insurance—and does not necessarily increase the number of rats killed per pound of poisoned bait. In dealing with high concentrations such as 1-64 or 1-100 we have, in addition to the greater cost of the poison, the increased possibility of the rats detecting the poison in some way, as was suggested by Manoa Experiment No. 25.

#### *Attrahents for Grain Baits:*

Many experiments on the subject of attrahents for grain baits have been conducted. Experiments performed locally in 1932 showed corn oil (1) to be superior as an attrahent to coconut or sunflower oil, and any one of these oils when mixed with paraffin was superior to pure paraffin which had previously been used for water-proofing torpedoes. Later studies indicate, however, that paraffin in any amount is

objectionable to rats. In 1935 several small tests (2) were conducted with Japanese cooking oils (Goma abura and Ageabura) at the Manoa substation, and they were found to be useful as possible substitutes for corn oil.

K. R. Gard (5), of the Colonial Sugar Refining Company, Ltd., Sydney, Australia, reported that raw linseed oil made their wheat baits very attractive and was then "being used in all baiting, both with traps and poisons." Experiments (3) on Oahu also showed raw linseed oil to be very attractive to rats and compared favorably with and sometimes exceeded corn oil or coconut oil. When any paraffin was used with either corn oil or coconut oil it so reduced their attractiveness that raw linseed oil was distinctly superior. Eckart (4) reported that "rats prefer raw linseed oil to corn oil" but he did not mention that paraffin had been mixed with the corn oil. Corn oil is more expensive (\$2.25 per gallon) than raw linseed oil (\$1.15 per gallon) or coconut oil (\$1.00 per gallon). Joseph Caceres, Health Officer, Island of Hawaii, has used bacon oil as an attractant for torpedoes with excellent results.

From the results of experiments by many workers, it is agreed that some oil attractant may be used with benefit in all rat baits. In the prebaited feeding-station method, however, the kind of oil appears of less importance than with the torpedo method, so long as some attractant is used to help the rats find the station quickly. The best attractants found thus far are corn oil, raw linseed oil and coconut oil, in that order.

The oil is not mixed with the bait in any definite proportion but only in quantities sufficient to flavor it and to attract the rats by its smell. In practical tests one quart of oil has been found sufficient for 10-15 pounds of rolled oats.

Rubbing raw linseed oil on the under side of the cover of each station when it is first put out in the field is undoubtedly an aid to the rats in finding the station and this should reduce the amount of oil necessary in the grain itself. Applying raw linseed oil to the hands, with or without gloves, may be beneficial in masking the human scent that is left on the pans and covers during normal handling. The value of this procedure has not been proved, but it may contribute to the general success of control measures.

#### *Benefit from Sweetening the Poisoned Bait:*

A recent test (Experiment No. 32) conducted at Pepeekeo Sugar Company and at the Hilo Variety station compared sweetened with unsweetened rolled oats, first unpoisoned and later poisoned. Regular feeding stations were placed in the field in pairs, one station of each pair contained sweetened and the other unsweetened rolled oats. All stations were changed to poisoned oats (1-200) in the usual way after 6-7 days exposure of unpoisoned grain.

The results, summarized from 70 pairs of stations, are given in Tables III, IV and V. The number of comparisons given in Table V (Summary of Differences) is less than the total number of pairs (70) because no differences were possible when both stations of a pair were entirely cleaned out.

The average daily consumption in grams is presented graphically in Fig. 6.

Graphic Presentation Of The Average Daily Consumption  
In Grams Per Active Station Of (1) Sweetened And (2)  
Unsweetened, Rolled Oats For The Three Priods Of The Test  
( From Table V )

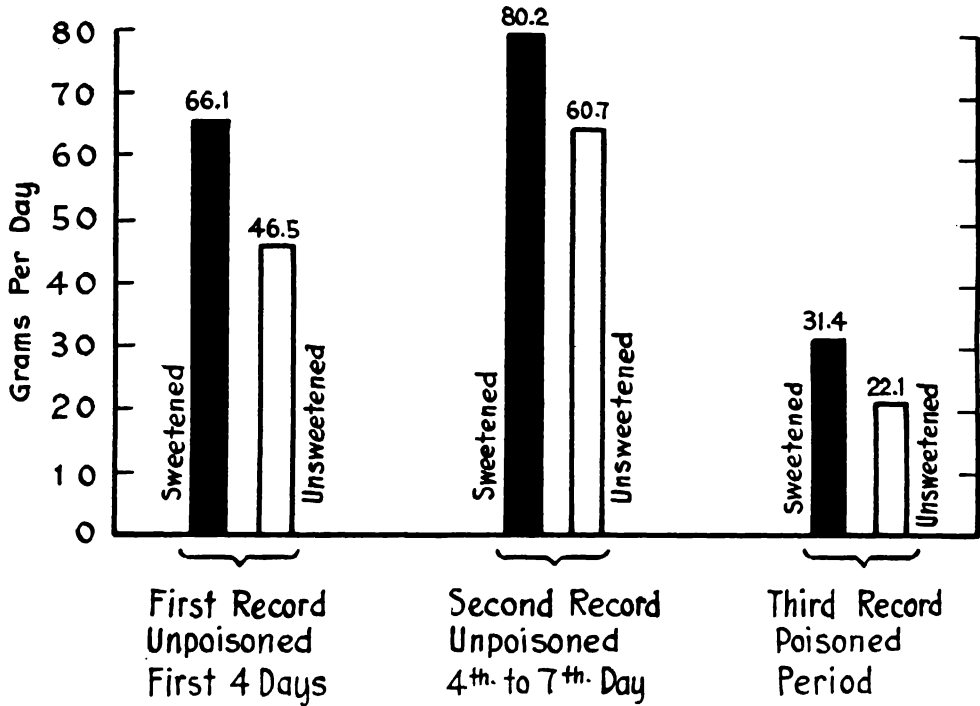


Fig. 6.

TABLE III

SUMMARY OF PREBAITED FEEDING STATIONS COMPARING SWEETENED  
AND UNSWEETENED ROLLED OATS

Pepeekeo Sugar Company and Hilo Variety Stations

Interval days after placing oats	4 Unpoisoned Un- Sweetened sweetened		3 Unpoisoned Un- Sweetened sweetened		3 Poisoned Un- Sweetened sweetened	
No. of stations showing no acceptance .....	12	12	2	5	11	15
No. of stations showing some acceptance .....	56	56	68	65	59	55
Total grams eaten .....	4570	3555	6440	5282	2012	1422
Total eaten expressed in pounds .....	10.06	7.83	14.18	11.63	4.43	3.13
Total difference or loss in lbs. when sugar was left out .....		-2.23		-2.55		-1.30
Total difference or loss expressed in per cent...		-22.2		-21.9		-29.3



TABLE IV

## STATION-TO-STATION COMPARISON OF CONSUMPTION OF OATS

Treatment	Total pairs visited by rats	Favoring sweetened	Favoring unsweetened	Even
Sweetened vs. unsweetened first 4 days; unpoisoned .....	60	33	17	10
Sweetened vs. unsweetened next 3 days; unpoisoned .....	69	43	11	15
Sweetened vs. unsweetened; poisoned period .....	64	40	18	6
Totals of all records.....	193	116	46	31

TABLE V

## SUMMARY OF DIFFERENCES (STUDENT'S METHOD)

No. of compari- sons	Treatment	Avg. daily consumption per active station (in gms.)	Loss for unsweetened gms. %	Signif.
	(First record, first 4 days, unpoisoned)			
52	Sweetened oats .....	66.1		
52	Unsweetened oats .....	46.5	—19.5 —29.5	Very high
	(Second record, next 3 days, unpoisoned)			
59	Sweetened oats .....	80.2		
59	Unsweetened oats .....	60.7	—19.6 —24.5	Very high
	(Third record, poisoned oats)			
64	Sweetened oats .....	31.4		
64	Unsweetened oats .....	22.1	—9.3 —29.6	Very high

*Discussion of Results:* A direct comparison of the total consumption of sweetened vs. unsweetened oats shows a consistent loss for the unsweetened oats of 22 per cent for the first 4 days, not poisoned; 22 per cent loss for the second unpoisoned period (3 days), and 29 per cent loss for the poisoned period. (See Table III.)

A station-to-station comparison of consumption for the 3 periods of feeding shows that out of a total of 193 paired records, 116 favored the sweetened oats, 46 favored the unsweetened and 31 were exactly even. (See Table IV.)

A statistical study of the summary of differences from the paired stations by Student's method shows a consistent loss for the unsweetened oats ranging from 25 to 30 per cent below the standard sweetened formula (See Table V), and indicates that the present sweetened poisoned formula\* should be continued without change. The odds based on these differences denote a very high significance.

These results indicate also that some benefit will accrue from sweetening all of the prebait used in the feeding stations. While the perfect prebait should be prepared exactly like the final poisoned bait except for the poison, we have not advocated this as plantation practice until we are sure that the additional expense of this extra

\* Rolled oats: 900 pounds.

Brown sugar: 28¾ pounds.

Corn syrup: 9 pounds.

Water: 8 gallons.

Thallium sulphate—variable according to orders of customer, ranging from 1-100 to 1-250.

(Courtesy of the Pacific Guano and Fertilizer Company.)

processing is justified, since this additional treatment would probably increase the cost of the unpoisoned bait 2 or 3 cents per pound.

#### PROCEDURE IN THE FIELD

##### *Distributing the Stations:*

The necessary quantity of the equipment previously described together with a supply of unpoisoned oats should be taken to the field and distributed at convenient points along the road. The distributor takes a load of approximately 20 complete stations and proceeds to set up stations in selected places. In previous work the stations were usually spaced from 90 to 100 feet apart along the level ditches, trails, roads, or edges of the field, placing about 4 stations per acre. The stations were spaced roughly equidistant, but the exact spot for a station was determined by the ease and speed of setting it upon fairly level ground. The stations should not be placed in a depression or ditch as heavy rains flood such areas and fill the grain pans. The stations should be placed where good cover is offered along the edges of, or slightly within, the cane or brush. No attempt should be made to hide the stations in the cane, although they should be off the trail sufficiently to avoid tripping over them during subsequent visits.

The stations may be spaced much closer (45-50 feet apart) where the fields border on a gulch or other wasteland with heavy growths of grass, brush, or other good shelter (i.e., *Panicum* grass, honohono, lantana, guava). It has been noted in the large field tests conducted at Grove Farm Company, and Kilauea Sugar Plantation Company that there are many definite, well-worn trails running directly from the gulch cover into the cane. The stations should be placed closer under these conditions to try to intercept and divert this direct rat traffic. A closely spaced line of stations along the edge of a rat-infested gulch, adjacent to very young cane is an ideal arrangement, and will greatly reduce or may entirely eliminate the necessity of placing stations inside the field at a later date, after the cane has closed in. This procedure should greatly reduce the average number per acre for the whole field. Our present data indicate that lines of stations within the field should not be more than 250 feet apart. The greater the distance between stations, the longer must be the period of exposure of unpoisoned oats before changing to poisoned in order to insure adequate control. Some record of the route and the location of the stations should be kept by the operator so that he can revisit them easily after the proper interval.

##### *Filling the Stations (See Figs. 3 and 4):*

During the first trip the stations are placed and a measured amount of unpoisoned oats poured into each pan. A convenient amount was found to be  $\frac{1}{4}$  pound, which exactly filled a kitchen measuring cup or a one-pound flat pineapple tin. In our experimental work, an accurate study of the consumption of oats was made and recorded for each station. This was done by measuring and estimating on the basis of one cupful ( $\frac{1}{4}$  pound) being divided into 100 parts and the consumption read in per cent. Commercially this is not necessary, but some sort of record should be made, especially during the last two days of unpoisoned prebaiting in order to be able to gauge intelligently how much of the expensive poisoned oats should be placed



after the second trip at which time any unpoisoned oats are removed and poisoned oats are substituted. Following three or four days of exposure with poisoned oats, the stations may be picked up on the fourth visit and moved to a new area. This procedure requires a minimum of 9 days for one poisoning cycle. Under special conditions it may be advisable to prolong the period of prebaiting with unpoisoned oats, but this will increase the consumption very materially. J. W. Anderson reports that he has had to wait as long as 9 days to build up a satisfactory acceptance of unpoisoned oats at the Kauai Variety station.

#### *Interval Between Poisoning Campaigns:*

Rats appear to migrate from distant wastelands to reinfest treated cane areas in a comparatively short time. Until we have more information it would seem advisable to repeat control operations in about 3 months. Special attention should be given to the edges of young cane adjacent to waste areas or near recently harvested fields.

Gulch areas adjoining harvested fields should be treated very soon after harvest while the localized food supply is low. When in doubt as to the necessity of repeating the poisoning process, test stations may be placed at strategic points for observation.

#### PERSONNEL

The success of this method of rat control is entirely dependent on the men in the field. They must be intelligent and absolutely reliable and able to work largely by themselves on their own initiative. They should have a genuine interest and pride in doing their work precisely and well. Some sort of a premium or bonus system of pay for rat control work would serve to emphasize their responsibility and reward their efficiency. As these men walk their routes through the fields they should seek to increase their efficiency in the placement of the stations by careful observations of the conditions of natural rat cover which lie immediately adjacent to the cane. The exercise of judgment in placing the required amount of poison in the various stations, based on a knowledge of previous consumption of unpoisoned grain, will prevent waste, especially during rainy weather. A brief field report showing the approximate consumption of bait by stations will help to keep up the interest and efficiency of the men as well as to afford a check on their effectiveness. The field form suggested in Fig. 7 may be useful for this purpose.

#### PRECAUTIONS FOR FIELD OPERATOR

After many days of observation while operating the feeding stations in the field, one is too well aware of the filthy mess that the rats can make around active stations during wet weather. In certain extremely wet areas, infectious jaundice (Weil's disease, Spirochetal jaundice) may be present among the rats. It is possible for the operator to catch the disease by contact of rat urine with a cut or scratch on the hand. To guard against this possible infection, the hands and arms should be washed in creolin solution before and after the work, and rubber gloves should be worn while handling the stations. If care is exercised to always handle the pans with one particular hand, perhaps a glove on that hand might be sufficient. It is also advisable to wear waterproof shoes or boots to prevent the possibility of infection by water through faulty footwear as has been reported in Australia.

## EXPERIMENTAL EVIDENCE

The experiments which were conducted in the development of this plan are briefly discussed in the following pages.

## KAILUA SUBSTATION

Two preliminary tests were conducted at Kailua to determine the value and practicability of feeding loose unpoisoned bait followed by poisoned bait in open feeding hoppers.

The first test (Experiment No. 27) consisted of only 13 stations placed along the stream bed at the Kailua substation. The results from these stations were so promising that further work was planned. The second test (Experiment No. 28) was started about one month later. The area included some of the same land along the stream and brushland that had been in the former skirmish test. Twenty-five stations were spaced 90-100 feet apart in a continuous line along the edge of the field. These were visited daily except Sunday for 19 days.

The results are tabulated in Table VI.


TABLE VI

SUMMARY OF PREBAITED FEEDING STATIONS—KAILUA SUBSTATION,  
EXPERIMENT NO. 28

Oats put out in 9 stations September 28, and in 16 more stations September 30, 1936

Dates	Total stations placed	No. stations showing acceptance	Total oats eaten per day (grams)	Avg. daily acceptance per active station (grams)	Total eaten per day (pounds)
UNPOISONED					
Sept. 29, 1936	9	0	0	0	0
Sept. 30, 1936	9	2	113	56	.25
Oct. 1, 1936	25	7	196	27.5	.43
" 2	25	13	613	47	1.35
" 3	25	19	783	41	1.73
" 4*	25	21	672	32	1.48
" 5*	25	21	673	32	1.48
" 6	25	18	698	39	1.54
" 7	25	20	936	47	2.06
" 8	25	22	1146	52	2.53
" 9	25	20	1288	64	2.84
" 10	25	17	1328	78	2.93
" 11*	25	25	1254	50	2.76
" 12*	25	25	1254	50	2.76
" 13	25	24	1771	74	3.90
POISONED					
" 14	25	18	783	43.5	1.73
" 15	25	0	0	0	0
" 16	25	0	0	0	0
" 17	25	0	0	0	0
" 18	25	0	0	0	0
" 19	25	0	0	0	0

\*=average of Sunday and Monday.

The total oats eaten per day has been plotted on the graph in  8.

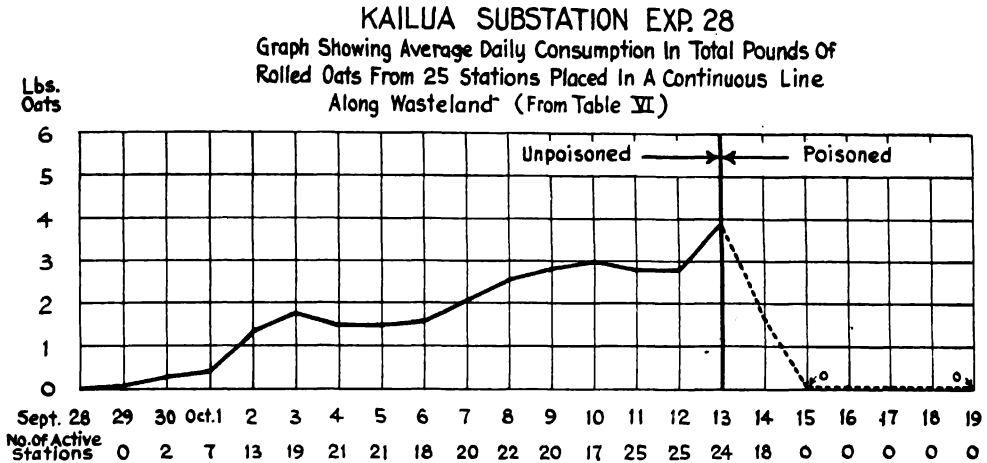


Fig. 8.

*Discussion:*

This area had a small rat population. Many stations showed no acceptance at first. It was several days before the rats would eat much of the unpoisoned bait. Bait consumption showed a gradual increase for 10 days or more. The average daily acceptance from 24 active stations reached 74 grams. When the poisoned bait was substituted the average consumption in grams for the first night dropped to  $43\frac{1}{4}$  grams in 18 active stations. This decline was heavier than expected and there was no further acceptance after the first night.

As these stations were in one continuous line along wasteland, the consumption of unpoisoned oats continued to increase slowly over a long period, as rats were being drawn from more distant cover on either side of the route. This later proved contrary to the usual experience found when the stations were distributed evenly throughout the field; and where consumption reached a maximum in about one week with little further increase after that time. These tests were sufficiently encouraging to warrant further study on a larger scale.

**WAIPIO SUBSTATION**

After the apparent success of the preliminary tests at the Kailua substation in October 1936, a more comprehensive field test (Experiment No. 31) was started on January 5, 1937, at the Waipio substation in an area of big cane reported to be rat infested. Rolled oats containing a small amount of corn oil attractant were used as the bait. Thallium sulphate at the rate of 1-100 was used in the poisoned oats.

This experiment was observed daily except Sundays for 19 days. The summary of the data obtained is presented in Table VII.

TABLE VII

## SUMMARY OF PREBAITED FEEDING STATIONS—WAPIO SUBSTATION, EXPERIMENT NO. 31

Rolled oats placed in first set of 48 stations January 5 and 6, 1937

Rolled oats placed in second series of 50 stations alternating with the first 48 on January 12 and 14, 1937

	Unpoisoned oats														Poisoned oats (1-100)		
	6	7	8	9	11	12	14	15	16	18	19	20	21	22	23	25	
Dates—January 1937 .....	1	1	1	1	2	1	2	1	1	2	1	1	1	1	1	2	
Interval between visits (days) .....	26	48	48	48	48	48	74	98	98	98	98	98	98	98	98	98	
Total stations placed .....	15	19	8	2	2	1	0	0	0	0	0	0	0	0	0	45	46
No. of stations showing no acceptance .....	11	29	40	46	46	47	48	48	48	48	48	48	48	48	48	48	50
No. of stations showing acceptance .....	278	641	880	1504	4075	3973	2576	2174	2525	3944	2582	2945	2480	352	23	10	
Total oats eaten (grams) .....							329	936	1010	3144	1663	2225	1447	176	5.7	0	
Avg. acceptance per active station between readings (grams) .....	25.3	22.1	22.0	32.7	88.6	84.5	53.7	45.3	52.6	82.2	53.8	61.4	51.7	19.5	7.6	5	
Avg. daily acceptance per active station (grams) .....	25.3	22.1	22.0	32.7	44.3	84.5	26.9	45.3	52.6	41.1	53.8	61.4	51.7	19.5	7.6	2	
Total eaten (pounds) .....							(61.65 lb—15 days)								(6.31 lb—5 days)		
Total consumed during each interval (pounds) .....	.61	1.41	1.94	3.31	8.98	8.77	5.68	4.79	5.56	8.69	5.69	6.49	5.46	.78	.05	.02	
Avg. daily consumption (pounds) .....	.61	1.41	1.94	3.31	4.49	8.77	2.84	4.79	5.56	4.35	5.69	6.49	5.46	.78	.05	.01	
							.37	2.06	2.23	3.47	3.66	4.90	3.19	.39	.01	0	

**WAIPIO SUBSTATION EXP. 31**  
Graph Showing Average Daily Consumption In Grams  
Per Active Stations ( From Table VII )

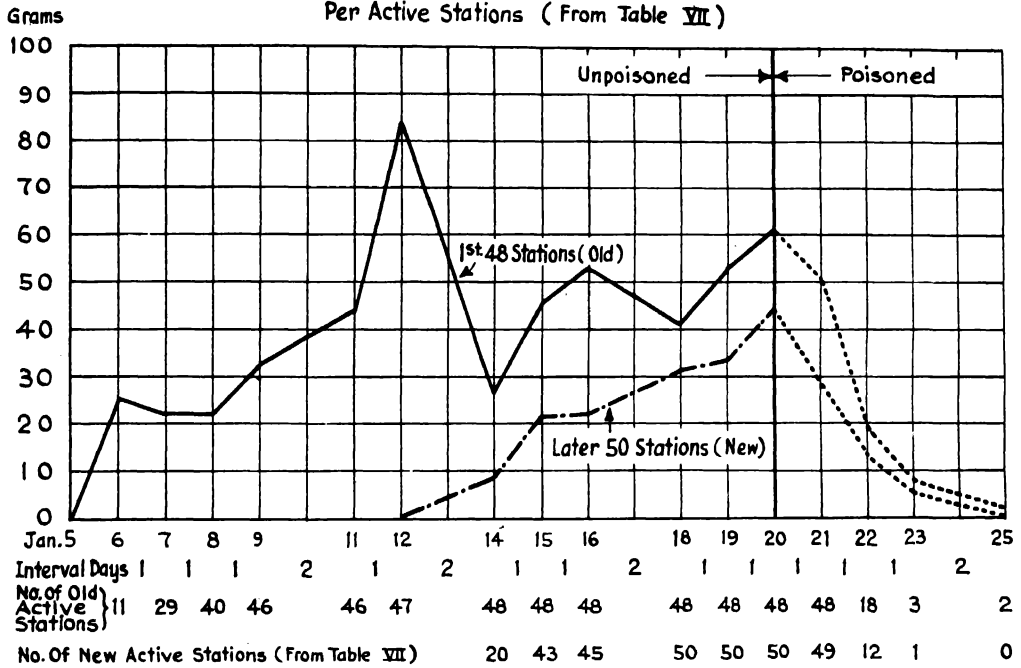


Fig. 9.

**WAIPIO SUBSTATION EXP. 31**  
Graph Showing Average Daily Consumption In Total  
Pounds Of Rolled Oats ( From Table VII )

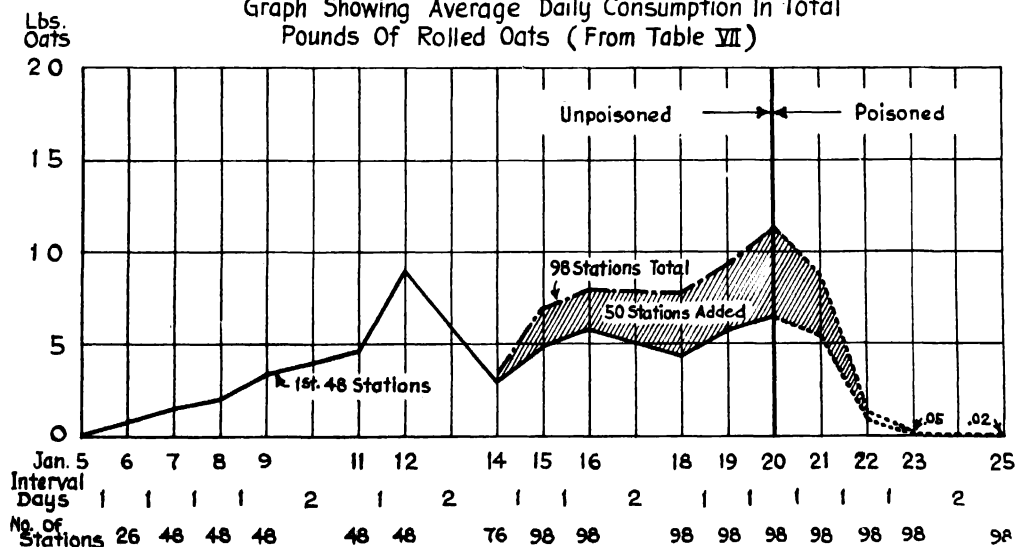


Fig. 10. First 48 stations shown by solid line. Later 50 stations were added (shaded area above solid line) making a total of 98 stations shown from June 14 to 23, 1937.



### *Discussion:*

This experiment offered an opportunity to test further the various types of covers and pans for the feeding stations. The simplest curved galvanized iron cover proved to be the best. Only 48 stations were operated for the first seven days. These were widely spaced in most instances to discover where the rats were living and to determine if they could be drawn to the food.

In a few days these stations became very active with the average daily consumption per station rising to 84 grams of unpoisoned oats on the seventh day. Fifty new stations were then placed in the same area, alternating with the original 48, reducing the spacing to about 80 or 100 feet, and increasing the total number of stations to 98. The immediate result was a heavy drop in the average consumption from the old stations of from  $84\frac{1}{2}$  to 27 grams, with only 20 new stations becoming active, averaging 8 grams for their first 2 days. This was a net reduction of 63.4 per cent in the total consumption for the field. This is graphically shown in the chart in Fig. 10 under the dates of January 12 to 16. We have been unable to give a positive explanation of this heavy drop in total consumption. It would be necessary to repeat this test to determine if it was more than a coincidence. One might conclude that the addition of these 50 stations to the same area was a disturbing factor which confused the rats and caused them to be suspicious of all stations including the particular ones that they had been in the habit of visiting previously. If there is any significance in this occurrence it suggests that the desired number of stations in a particular area be started all at one time and that no changes in location of stations within the area be made after the first day.

The total consumption for the field had almost returned to normal in three days, with the new stations receiving less attention than the old stations.

Unpoisoned oats were exposed in all stations for 8 days after which time poisoned oats were substituted. The average consumption from the old stations dropped 14.7 per cent from 61 grams for the last night of unpoisoned oats to 52 grams for the first night of poisoned oats. At the same time the new stations dropped 32 per cent from  $44\frac{1}{2}$  grams each of unpoisoned oats to  $29\frac{1}{2}$  grams of poisoned oats. (See Table VII and Figs. 9 and 10.)

Of the total amount of poisoned oats eaten, 87.6 per cent were eaten on the first night of exposure, 12 per cent on the second night, with only .4 of one per cent on the third and fourth nights combined, after which time no more poisoned oats were taken. Ninety-seven out of the 98 stations were visited on the first night of poisoned oats, 30 stations were revisited on the second night and only 4 on the third and 2 on the fourth nights, after which all stations remained undisturbed. The amounts consumed at these 6 stations on the third and fourth nights were so small that it could scarcely be measured but it was estimated at 5 grams each. The smell of dead rats in the field was reported by the field personnel.

Unpoisoned grain was again placed in all 98 stations twelve days after the first poisoning. There was a slight disturbance of the grain in 13 stations but the amount of oats missing was too small to measure in the field. This indicated that only a few stray mice or rats had escaped the poison campaign or had later migrated into the treated area.

## WAIMANALO SUGAR COMPANY

Early in January 1937, Manager Bennett, of the Waimanalo Sugar Company, discovered that rats (determined to be *hawaiiensis*) from the forest area above Waimanalo, had invaded and were doing great damage to some small blocks of 31-1389 cane. These areas offered an excellent opportunity for trying out the feeding-station method of rat control on a larger scale and under wet conditions.

Accordingly, an experiment (No. 30) was installed in this area consisting of 116 stations spaced 60 to 90 feet apart along roads and ditches, at the edge of Panicum grass along a reservoir, and along a stream. Only in a few cases was it deemed necessary to go into big cane to place the stations. Various types of tin pans and covers were used but the most satisfactory station consisted of a "covered-wagon" type of cover placed over a small square baking pan. Other types of covers and pans which would not nest together, proved very troublesome and bulky to handle. The bait used was rolled oats with about one quart of corn oil mixed with each 10-12 pounds of oats, both unpoisoned and poisoned. The poisoned oats were treated at the rate of one pound thallium sulphate to 100 pounds of rolled oats. Unpoisoned oats were fed for seven days followed by poisoned oats. Notes were taken after 2 days of poisoned oats and again after 7 days. Unpoisoned oats were again returned to all stations for 8 days as a check on the effectiveness of the poisoned oats.

The detailed consumption data were tabulated and summarized. Only the summarized data are presented in Table VIII.

TABLE VIII

SUMMARY OF PREBAITED FEEDING STATIONS—WAIMANALO SUGAR COMPANY,  
EXPERIMENT NO. 30

Rolled oats placed in 116 stations on January 25, 1937							
	—Unpoisoned oats—				Poisoned oats (1-100)		Unpoisoned oats
Dates—1937	Jan. 27	29	30	Feb. 1	3	8	16
Interval between visits (days).....	2	2	1	2	2	5	8
Total stations placed .....	92	116	116	116	116	116	116
Number of stations showing no acceptance .....	7	5	10	2	17	89	99
Number of stations showing acceptance .....	85	111	106	114	99	27	17
Total oats eaten (grams).....	4,851	9,867	6,156	9,785	2,281	329	217
Average acceptance per active sta- tion between readings (grams)...	64.8	88.9	58.1	85.8	23.1	12.2	12.8
Average daily acceptance per active station (grams) .....	32.4	44.4	58.1	42.9	23.1	12.2	1.6
Total eaten (pounds).....	(68.9 lbs.—7 days)				(5.75 lbs.— 7 days)		(0.48 lbs.— 8 days)
Total consumed during each interval (pounds) .....	12.1	21.7	13.6	21.5	5.0	0.75	0.48
					Total only		
Average daily consumption (pounds)	6.1	10.9	13.6	10.8	5.0	0.75	.06
Ratio of poisoned to unpoisoned oats 1:12							

The average daily consumption in total pounds of oats eaten in 116 stations is plotted in Fig. 11.

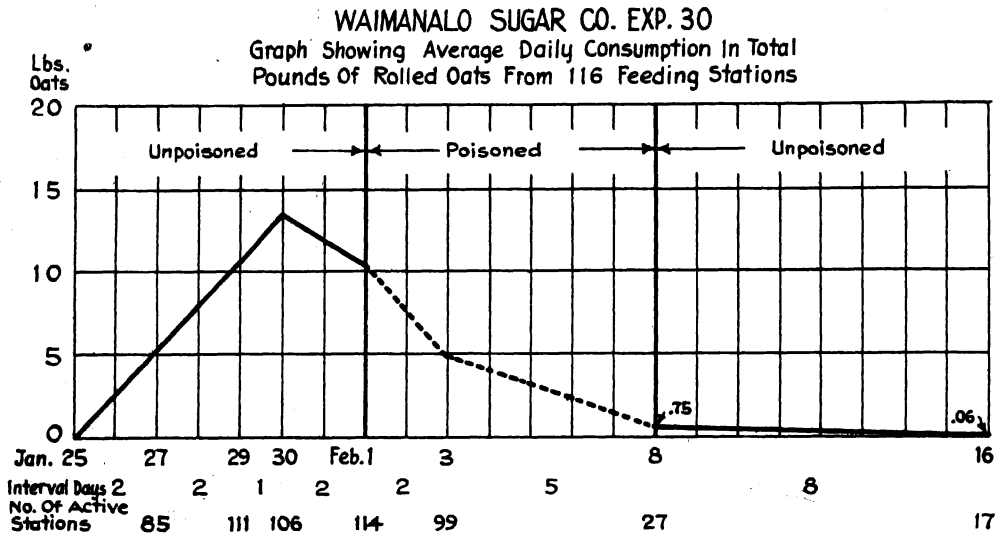


Fig. 11.

*Discussion:*

Contrary to previous experience, good consumption of unpoisoned oats was obtained on the second day, and this did not increase after the fifth day. This was probably due to the less suspicious nature of the small native Hawaiian rat, who is reputed to take poisoned food more readily than other more cautious species.

The drop in the consumption curve on February 1, just prior to poisoning was due to the fact that there was not enough bait placed in the pans to feed the rats for two days. This resulted in many empty pans before the rats had obtained their fill.

When poison was applied, 15 active stations became inactive and the average consumption per station dropped to 53.6 per cent of the last 2 days of unpoisoned oats. We cannot explain this drop unless it was due to the high concentration of thallium affecting the rats so quickly that they could consume but a small amount of the poisoned oats. But as a lesser amount was required to kill,\* the bait was still effective (see Table VIII) as dead rats were easily found over the area beginning on the second day. From these results the use of a high concentration (1-100) of poison may be open to question when used in feeding stations.

For the purpose of checking on the effectiveness of the poison, unpoisoned grain was again placed in all stations, seven days after any remaining poisoned oats had been removed. The results showed a very small consumption in only 17 stations out of the original 116, all of which were located on the margin of the unpoisoned area. This indicated that the poison was effective within the area.

On account of wet weather (19½ inches of rain) during this test, oats left untouched after 3 or 4 days showed varying degrees of mold, depending on air circulation around the individual stations. From a few less active stations it was occasionally necessary to discard a small amount of dirty and powdered oats, but very few oats were wasted and no spoilage occurred at the active stations. Poisoned oats should be either collected or discarded after 3 or 4 days exposure during wet weather.

\* Upon dissecting a poisoned rat from the "K" reservoir area, it was found that the poisoned oats eaten were about equal in volume to a good-sized garden pea.

## KILAUEA SUGAR PLANTATION COMPANY

Two extensive tests with prebaited feeding stations were conducted at Kilauea Sugar Plantation Company. These studies were made in big cane on a much larger scale than had been possible at any time previous. Both tests were visited oftener and continued longer, than would be necessary for a practical control, for the purpose of determining what was happening in each field.

(*Kilauea Experiment No. 1.*) The area chosen (Field 20) for this first experiment contained 45 acres of POJ 2878 and 34 acres of Badila, all one year old. Two hundred and fifty-five feeding stations of the standard type previously described were placed in this field on April 10th. Later, 32 additional stations were placed in certain areas purposely omitted previously in order to determine a proper spacing between stations. The total stations placed in the field amounted to 287 which was an average of 3.6 stations per acre. Raw linseed oil was rubbed on the inside of each cover as an attractant when they were first placed in the field. Poisoned and unpoisoned oats were used in these stations as follows:

(1) 6 days with unpoisoned oats; (2) 6 days with poisoned oats; (3) 4 days with unpoisoned oats, for a second time; and (4) 2 days with poisoned oats, a second time.

The detailed consumption by stations was carefully tabulated and summarized. The summarized data are presented in Table IX.

TABLE IX

## SUMMARY OF PREBAITED FEEDING STATIONS—KILAUEA SUGAR PLANTATION COMPANY, FIELD 20, EXPERIMENT 1

Rolled oats* placed in 255 stations on April 10, 1937							
	Unpoisoned oats			Poisoned oats (1-250)		Unpoisoned oats	Poisoned oats (1-250)
Dates—April 1937 .....	12	14	16	19	22	26	28
Interval between visits (days)	2	2	2	3	3	4	2
No. of stations showing no acceptance .....	168	9	0	9	233	218	246
No. of stations showing acceptance .....	84†	243†	252†	243†	19	34	6
Total oats eaten (grams).....	2,302	20,390	26,292	10,950	101	504	41
Avg. acceptance per active station between readings (grams) .....	27.4	83.9	104.3	42.9	5.2	14.8	6.8
Avg. daily acceptance per active station (grams).....	13.6	42.0	52.2	42.9	5.2‡	3.4	3.4
Total eaten (pounds).....	(108 lbs.—6 days)			(24.34 lbs.— 6 days)		4 days 1.1	2 days 0.09
Total consumed during each interval (pounds) .....	5.1	44.9	57.9	24.12	.22	1.1	0.09
Avg. daily consumption (pounds) (252 stations)....	2.5	22.5	29.0	24.12	.22	.27	0.09
Total only‡							

Ratio of poisoned to unpoisoned oats 1:4.4

\* Coconut oil used with both unpoisoned and poisoned oats, approximately one quart to fifteen pounds of oats.

† Three stations omitted because records were lost on second day of poisoning due to a five-inch rain which washed out the stations.

‡ When poison was applied, 87 to 90 per cent was consumed the first night with a rapid decrease each succeeding night, so total only can be shown. Poisoned rats cannot return to eat the following day.

### *Discussion:*

After the first two days exposure of unpoisoned grain only one-third of the stations showed any activity, with an average of only 13.6 grams of oats consumed per active station. Many tracks of mice were noted, but few evidences of rats. Even when the stations were deliberately placed on a fresh rat trail coming out of the gulch cover, few or no oats were eaten. In four days, however, all but 9 stations out of the total of 255 had become active with an average daily consumption of 42 grams for each. Those stations located on fresh rat trails from the gulch were now among the most active stations in the field. After two more days exposure (total 6 days) all stations (no exceptions) had become active with an average daily acceptance of 52 grams per station. In a few cases rats dug tunnels under emptied pans in an attempt to locate additional food. In one case a fresh hole had been dug next to the station, indicating a desire to live close to the source of the new food. When poison was applied, 9 stations became inactive leaving 243 with an average consumption of 43 grams, a decline of 9 grams or 17 per cent from the best day of unpoisoned acceptance. This decline in consumption on the night of substituting the poisoned grain has always occurred and varies only in degree. The cause is not known. It may indicate a certain degree of detection of the poison or merely that the rats cannot eat as much of the poisoned as unpoisoned oats during one night. Perhaps ill effects following their first visit early in the evening, prevents them from eating again before hiding for the following day. As the rats were able to visit and eat poison but once, most of the poisoned oats were consumed on the first night of poisoning, although the figure obtained covered 3 nights. Three stations were discarded due to a heavy rain which completely flooded them the second day of poisoning.

The average daily total consumption of unpoisoned oats in 252 stations for 6 days follows: first 2 days, 2.5 pounds; third and fourth days, 22.5 pounds; fifth and sixth days, 29 pounds, making a total of 108 pounds of unpoisoned oats eaten during prebaiting. During the following 6 days, 24.3 pounds of poisoned oats were eaten, indicating a ratio of 4.4 pounds of prebait eaten for each pound of the poisoned food.

For the purpose of experiment the poison was left in the field a second period of three days after the first record of poison had been taken. Only 19 stations or 7 $\frac{3}{4}$  per cent showed any further disturbance of the poisoned grain, with only a total measured amount eaten of .22 pound or 9/10 of one per cent of the amount eaten in the first three days of poison. It therefore seems questionable whether it is worth while to leave the poison in the field the extra three days. It is quite probable that most or all of this small consumption occurred on the fourth night immediately following the first record.

The average daily consumption of rolled oats in pounds (Table IX) for the entire test is shown graphically in Fig. 12.

### *Distribution of Rat Population:*

The detailed data, station by station, have been plotted on the map of the field shown in Fig. 13. A large dot was placed on this map for each 1/40 pound or 11.3 grams of poisoned oats consumed. This amount is a lethal dose for 3.4 pounds of rats and could account for 3 or 4 average rats and allow a margin for some of them





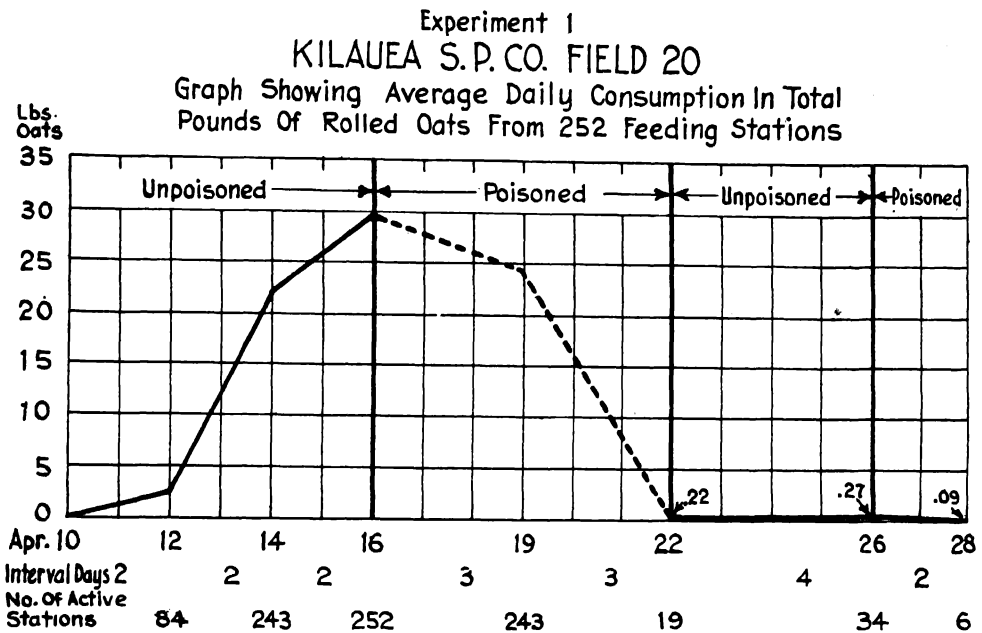


Fig. 12.

to eat more than the minimum lethal dose. By this method a graphic picture is presented of the distribution of the rats in the field in relation to natural cover occurring around the field.

The areas along the clean open pasture and young cane harbored comparatively few rats. An extremely heavy infestation occurred along the gulches where the natural cover of Panicum grass, honohono, morning glory and lantana make the area almost impenetrable. Along this area there were many distinct and clear-cut, rat trails through the grass from the gulch direct into the cane. The greatest damage to cane invariably occurred at the heads of the small gullies or field drains.

#### *A Study of Distance Between Stations:*

Four level ditches and a 350-foot strip along the gulch were purposely omitted in the first poisoning. These areas are blank on the map in Fig. 13. All of the poisoned oats were picked up and unpoisoned oats substituted in all 255 stations on April 22nd. On this same day 32 new stations were placed in these four level ditches and the 350-foot strip along the gulch which had been omitted in the original placement. These were filled with unpoisoned oats also. On April 26 all stations in the field, including the 32 new ones, were filled with poisoned oats. Two days later (April 28) the amount of consumption was measured and recorded. The results are summarized in Table X and plotted on the map in Fig. 14.



TABLE X

SUMMARY OF PREBAITED FEEDING STATIONS IN AREAS PREVIOUSLY OMITTED  
Oats put out April 22, 1937

	Unpoisoned oats	Poisoned oats (1-250)
Dates—April 1937 .....	26	28
Interval between visits (days).....	4*	2
Total stations placed† .....	31	31
Number of stations showing no acceptance.....	8	17
Number of stations showing acceptance.....	23	14
Total oats eaten (grams).....	1362	154.4
Average acceptance per active station between readings (grams) .	59.2	11.0‡
Average daily acceptance per active station (grams)§.....	14.9	11.0‡
Total eaten (pounds) .....	3	.34‡
Total average daily consumption (pounds).....	.75	.34‡

Ratio: Poisoned to unpoisoned 1:8.8

\* Poisoned at end of 4 days prebait to save time, as very little activity was evident in these areas.

† One station in low spot lost by flooding.

‡ 85 to 90 per cent of the poisoned oats were eaten the first night, so only totals are shown.

§ The decline in daily consumption when poison was applied amounted to 14.9—11.0=3.9 or 26 per cent below the average consumption of all 4 days of prebait.

The final acceptance of poisoned oats in these level ditches was very small as compared with the original acceptance in the field as a whole. Relatively few rats and mice were left in the level ditches which had not been treated originally. This indicates that a large number of the rats originally in this area were drawn greater distances to the original stations in the adjacent level ditches (see Fig. 14). There remained a few rats and mice who had escaped the first poisoning because of this increased distance between the original lines of stations. Judging from the results obtained in this test, we cannot expect complete control when the lines of feeding stations are spaced 250 feet or more apart, without greatly increasing the length of the unpoisoned feeding period.

#### *Unpoisoned Oats Following the Poisoned:*

After the 6 days of poisoning, unpoisoned rolled oats were again exposed for four days in all stations. There were 34 stations (13 per cent) in which the oats had been disturbed or some slight amount eaten during this four-day period. A total of 1.1 pounds of unpoisoned oats was eaten, averaging .27 pound per day, or slightly over one per cent of the average daily amount consumed before poisoning. Judging from the size of the droppings left, mice or young rats were the chief survivors.

These stations showing a return of rodents were plotted on the map (indicated stations enclosed in circle in Fig. 14) and were found to be in groups on the edge of the areas omitted in the first poisoning. (See Stations 17, 18, 19; 55, 56; 65, 66; 165, 167, and 169.) At these points the station routes were 350 or more feet apart. This evidence shows that some rats had been left in the wider areas omitted in the first poisoning. One remaining group of stations (148, 149, and 150) was located

along the gulch next to an unpoisoned area. Here again, rats survived where the spacing between stations was too great. It is possible that young rats just past the weaning stage, traveling in a wider circle each day, had at last moved far enough from their nest to contact one of these feeding stations.

Poisoned oats were again\* (April 26) placed in all (34) stations showing the slightest disturbance of the unpoisoned oats during the four-day period. Only 6 stations showed a measurable consumption, a total .09 pound or less than 4/10 of one per cent of the amount of poison eaten originally which was negligible.

#### *Cost of Poisoning:*

There were 284 stations in this 79-acre field which is an average of 3.6 stations per acre. Excluding the cost of car transportation to and along the field roads and the investment in equipment, a 9-day schedule of visitation of an average of 3.6 to 4 stations per acre may be summarized as follows:

#### *Labor†:*

1st trip—Distributing the stations, about.....	16 hours
(should place about 20 stations per hour)	
2nd trip—Refilling the stations, 4 days later, about.....	11 hours
(should cover 22-25 stations per hour)	
3rd trip—Poisoning the stations, about.....	13 hours
(2 to 3 days later)	
4th trip—Picking up stations, about.....	13 hours
(3 or 4 days later)	
	<hr/>
	Total 52 hours
Labor (conservative estimate) .....	\$10.40
Unpoisoned oats—110 pounds at 4 cents per pound.....	4.40
Poisoned oats—25 pounds at 13 cents (1-250).....	3.25
Coconut oil—3 gallons at \$1.00.....	3.00
	<hr/>
Total cost of labor and materials to treat 79 acres.....	\$21.05
Total cost of labor and materials to treat 1 acre.....	\$ .266

This cost figure would be subject to fluctuation according to local conditions but compares very favorably with previous methods which used the torpedo or sausage bait.

#### *Summary:*

These studies confirm our previous findings and prove that the rats at Kilauea respond to the feeding-station method in a satisfactory manner, as they did on Oahu plantations.

\* This is the same time that poison was placed for the first time in the 32 new stations which had been purposely omitted, to study the distances rats could be drawn.

† Wet cane greatly reduces labor efficiency in caring for the feeding stations.

The greatest concentration of rats occurs along the gulches and wasteland where permanent cover is always present. This suggests that an early intensive campaign be concentrated along natural rat harbors near young cane. The feeding-station method is especially adapted to this scheme of control.

From the results of this test we cannot expect complete control when the lines of feeding stations are spaced 250 feet or more apart, without greatly increasing the length of the prebaited feeding period.

For practical purposes 3 days exposure of poison is sufficient as only one per cent additional oats was eaten during the second three-day period.

After 6 days of poisoning, a return to unpoisoned grain gave consumption of only one per cent of the original average daily amount, showing a very small remaining population, which would not warrant an immediate re-poisoning. It would be more practical to repeat the treatment in 2 to 3 months, giving the small rats a chance to grow up enough to travel, but before another generation of young had developed.

The cost of labor and materials, excluding transportation and investment in equipment, need not rise above 30 cents per acre for one poisoning. This charge would cover the installation and necessary visitations of an average of 4 stations per acre for a period of 9 days.



Fig. 15. Typical *Panicum* grass-covered drain in Field 1, Kilauea Sugar Plantation Company where Experiment No. 2 was carried out. This excellent rat harbor was heavily infested following the harvesting of adjacent cane areas.



Fig. 16. Edge of *Panicum* grass-covered drain in harvested area of Field 10 showing feeding stations being placed. The consumption of the active stations just previous to poisoning amounted to an average of 80 grams per night which was the highest for any field studied so far. This indicated an abundance of rats as these stations were spaced only 40 feet apart.

(*Kilauea Experiment No. 2.*) The purpose of Experiment No. 2 was to draw the rats out of a field drain or gulch between Fields 10 and 1. The cane in these fields had been harvested about April 1 and the rats from the cane had been forced to move into the heavy growth of *Panicum* in large numbers. Their presence was definitely indicated by much freshly eaten waste cane left along the edge of the field. Two small, direct-poison skirmish tests using sausages, oat briquettes, and loose oats placed in standard feeding stations resulted in very poor acceptance. Trapping was resorted to beginning April 15, by K. Harada, agriculturist, Kilauea Sugar Plantation Company. His catch in traps, spaced 20-25 feet apart was good, ranging from 15 to 20 rats per 100 trap-days. After 10 days the traps were moved farther down the gulch toward the sea and a set of 59 feeding stations, spaced 40 feet apart was placed along the edge of the *Panicum* grass cover (see Fig. 15). These stations were kept filled with unpoisoned oats for 7 days followed by poisoned oats for 7 days. Unpoisoned oats were again placed in the stations and observed after 3 days to check the thoroughness of the poisoning.

The data were recorded, station by station, and the summary is given in Table XI.

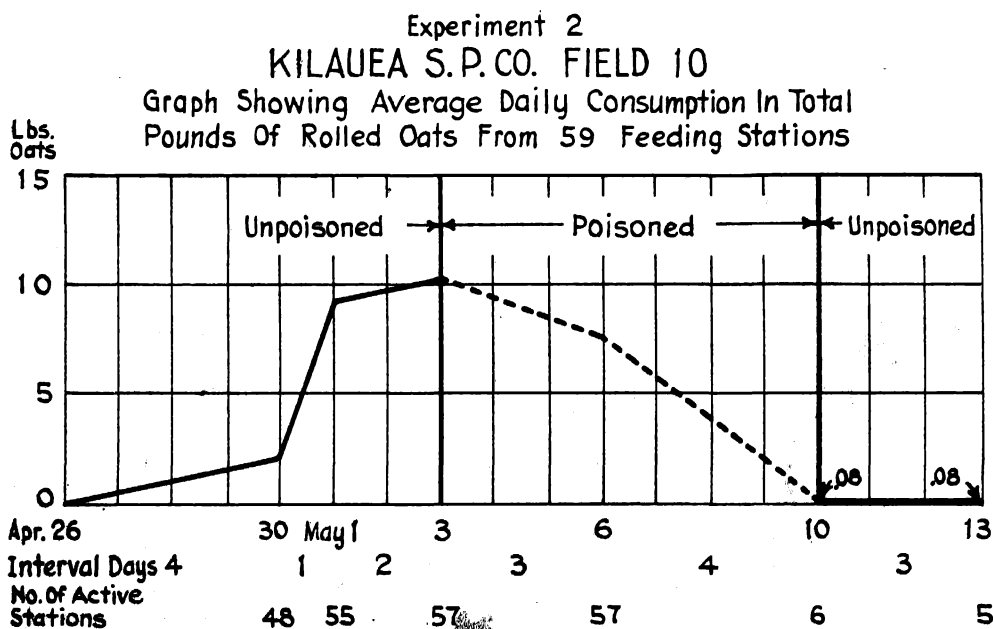
TABLE XI

## SUMMARY OF PREBAITED FEEDING STATIONS—KILAUEA SUGAR PLANTATION COMPANY, FIELD 10, ALONG DRAIN, EXPERIMENT 2

Rolled oats placed in 59 stations on April 26, 1937

	—Unpoisoned oats—			Poisoned oats (1-250)		Unpoisoned oats
Dates—1937	Apr. 30	May 1	3	6	10	13
Interval between visits (days).....	4	1	2	3	4	3
Number of stations showing no acceptance .....	11	4	2	2	53	54
Number of stations showing acceptance .....	48	55	57	57	6	5
Total oats eaten (grams).....	4,239	4,163	9,149	3,382	40	120
Average acceptance per active station between readings (grams)...	88.3	75.6	160.5	59.4	6.8	23.8
Average daily acceptance per active station (grams) .....	22.0	75.6	80.2	59.4	6.8	7.9
Total eaten (pounds).....	(38.6 lb—7 days)			(7.53 lb—7 days)		(.25 lb—3 days)
Total consumed during each interval (pounds) .....	9.3	9.2	20.15	7.45	.08	.25
Average daily consumption (pounds) (59 stations) .....	2.3	9.2	10.1	See above		.08
Ratio poisoned to unpoisoned oats 1:5.3						

The average daily consumption in total pounds of oats eaten in 57 stations is plotted in Fig. 17.



## -Discussion:

Typical of all prebaited feeding tests, the number of active stations as well as the average consumption per station increased rapidly for 5 or 6 days then materially lessened as maximum consumption was approached. Only two stations remained inactive throughout, due to a poor guess in placement.

The consumption of the active stations just previous to poisoning amounted to an average of 80 grams which was the highest for any field studied so far. This indicated an abundance of rats when we realize that these stations were only 40 feet apart.

When poison was applied there was a drop in consumption of 2.5 pounds or 25 per cent under the maximum of 10.1 pounds of the preceding day. This is a greater decline than in the preceding test but we have no proven explanation. It should be noted that there was almost no poison consumption after the third day of poison. This test gave further evidence that 3 or 4 days exposure of poison was sufficient.

Unpoisoned grain was again returned to prove the effectiveness of the poison. Only four stations showed a measurable consumption for the 3 days, averaging only 8/100 pound per day or 8/10 of one per cent of the daily consumption before poisoning. This indicated that very few mice or rats still existed in the treated area or had come from greater distances to the food. This border effect by stray rats will be less when the treated areas are in larger units.

After efforts of direct poisoning (Skirmish Tests 1 and 2) were ineffective, and even following intensive trapping for several days, this group of feeding stations, closely spaced along the field drain covered with *Panicum* grass, adjacent to a recently harvested field, still gave the highest average consumption of poison per station of any test that we have conducted so far.

#### GROVE FARM COMPANY, LTD.

Field 23 consisting of 142.7 acres of one-year old, unirrigated Yellow Tip cane was chosen as the site for the field test at Grove Farm Company. Between March 29 and April 2, 1937, ten half-bags of crushed oat torpedoes had been scattered, particularly along the edges of the field, roads, and trails. These torpedoes were much in evidence everywhere that feeding stations were placed. Three hundred and twenty-eight stations were spaced from 60 to 100 feet, depending on location. The spacing was reduced to 60 feet in some places where heavy vegetation adjacent to damaged cane indicated an abundance of rats. Many of the feeding station covers used in this test were heavy pieces of galvanized roofing which proved very awkward and expensive to carry into the field or along wasteland. Raw linseed oil was rubbed on the inside of each cover as an attractant when they were placed in the field.

As this field was unirrigated and carried cane one year old, it was impossible to place stations inside the cane away from roads or trails. The large solid blocks of cane were inaccessible, so the stations had to be placed mostly around the edges and along the roads and on a few trails. On this account the distribution of stations averaged only 2.3 per acre, although we aimed to have about 4 stations per acre. Poisoned and unpoisoned oats were used in these stations beginning April 9 and 10 as follows:

(1) 3 days with unpoisoned crushed oats; (2) 8 days with unpoisoned rolled oats; (3) 8 days with poisoned rolled oats; and (4) 5 days with unpoisoned rolled oats a second time.

The detailed consumption by stations was carefully tabulated and summarized. The summary data are presented in Table XII.

TABLE XII

SUMMARY OF PREBAITED FEEDING STATIONS—GROVE FARM COMPANY, LTD.,  
FIELD 23

Crushed oats put out April 9-10

Changed to rolled oats April 13

Total=328 stations

	Unpoisoned oats					Poisoned oats (1-250)		Unpoisoned oats
Dates—1937	Apr. 13	15	17	19	21	24	29	May 4
Interval between visits (days)...	3	2	2	2	2	3	5	5
Number of stations showing no acceptance .....	322	264	175	137	56	88	289	159
Number of stations showing some acceptance .....	5	54	153	191	272	240	39	169
Total oats eaten (grams).....	74.0	2,208	9,940	13,966	29,165	6,316	316	2,942
Avg. acceptance per active sta- tion between readings (grams)	15.0	40.9	64.9	73.1	107.3	26.3	8.1	17.4
Avg. daily acceptance per active station (grams) .....	4.5	20.4	32.5	36.5	53.6	26.3	8.1	3.5
Total oats eaten (pounds).....		(121.7 lb—11 days)					(14.6— 8 days)	(6.5— 5 days)
Total oats eaten during each interval (pounds) .....	.16	4.8	21.9	30.8	64.2	13.9	0.7	6.5
Avg. daily consumption (pounds)	.05	2.4	10.9	15.4	32.1	13.9	0.7	1.3
						14.6 lb		

The average daily consumption of rolled oats in pounds is shown graphically in Fig. 18.

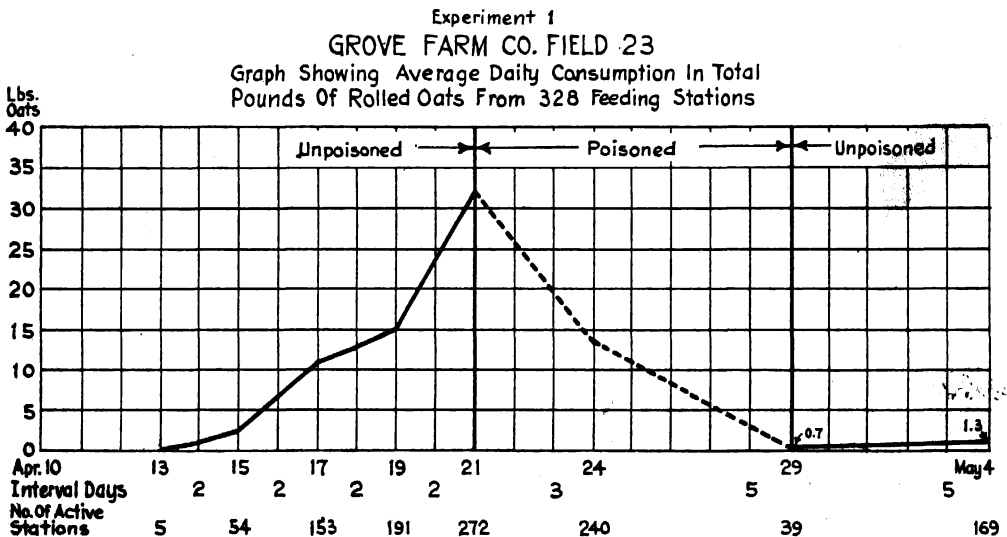


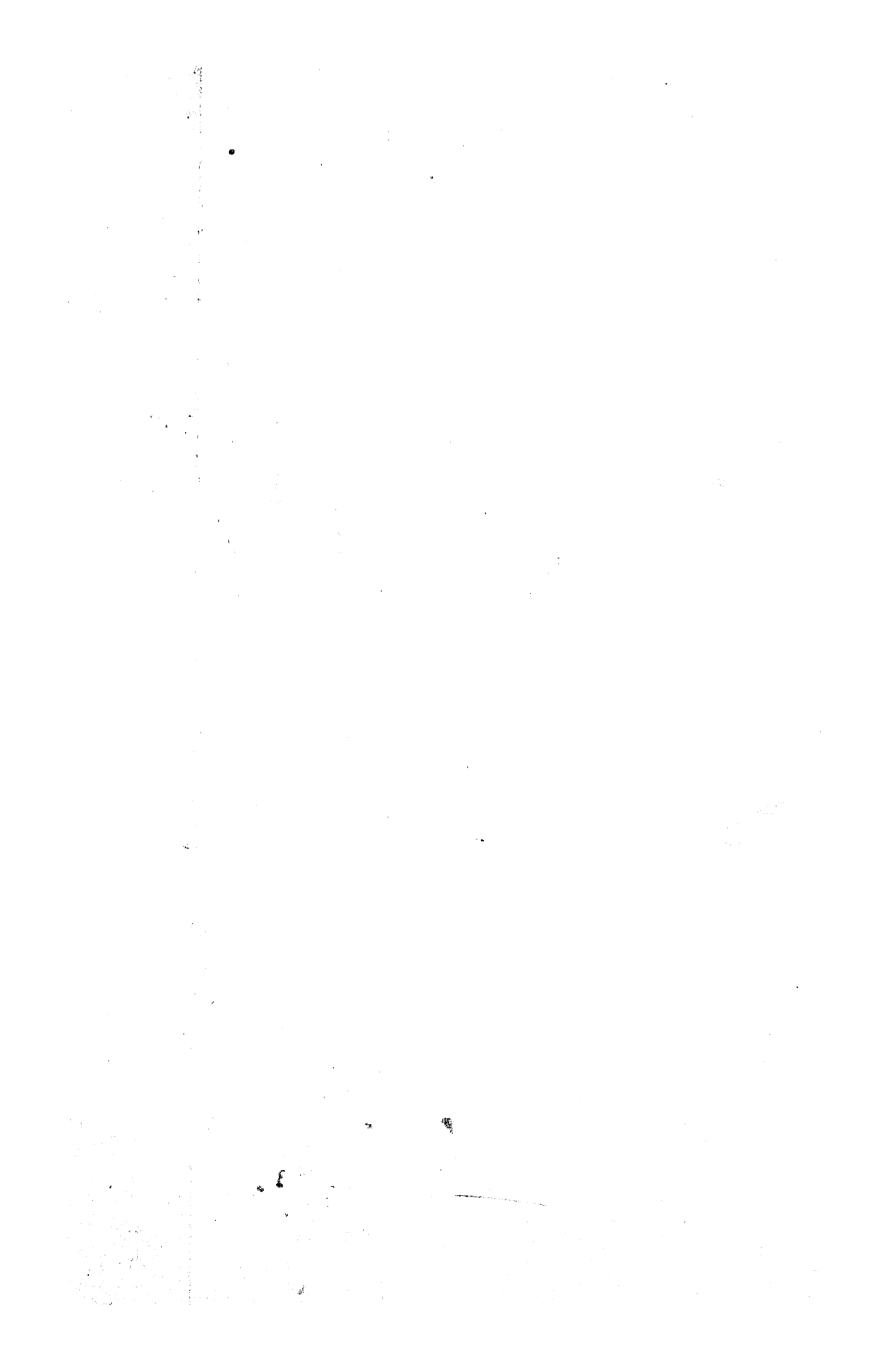
Fig. 18.

*Discussion:*

Due to difficulty in securing rolled oats when this test was first installed, crushed instead of rolled oats were used so that the test could begin promptly on April 9 and 10th. However, this substitution proved to be a waste of time. Only 5 stations in the entire field showed any consumption of these crushed oats during the first 3 days of exposure; then, all stations were changed to rolled oats. After 6 days with rolled







oats, 55 per cent of the stations were active with an average daily consumption of 36.5 grams. However, between the sixth and eighth day, the total consumption in the field doubled, 272 stations (83 per cent) being active with an average daily consumption of 54 grams. The other 56 stations were located in areas apparently free of rats.

Poison was finally applied to all active stations after 8 days of unpoisoned rolled oats. Poisoned oats consumption amounted to a total of 14.6 pounds eaten in 240 stations and represented a heavy decline from the peak of 32.1 pounds average for the previous 2 days (see Table XII). This slump is a much greater drop than occurred in either of the Kilauea Sugar Plantation Company tests. The cause is not known, although there is the suspicion that many of the rats that had survived the recent torpedo campaign (March 28 to April 2) were bait-shy and refused to eat strange food. However, in spite of all handicaps, 14.6 pounds of poisoned grain were consumed in 240 stations, resulting in a large number of rats being killed which had lived through the torpedo campaign of only 3 weeks previous. A larger amount of unpoisoned oats was consumed on account of the necessary extra days of feeding. This increased the ratio to one pound of poisoned to 8.3 pounds of unpoisoned grain. Experiments Nos. 1 and 2 at Kilauea Sugar Plantation Company showed ratios of 1:4.4 and 1:5.3 respectively.

For experimental purposes the poison was left in the field a second period of 5 days after the first record had been taken. There were 39 stations or 12 per cent which showed some disturbance of the poisoned grain with a total of .7 pound eaten during the 5 days. This amounts to 5 per cent of the amount eaten during the first 3 days of poison. In this case it might be worth while to let the poison stay 4 days before removing, in order to catch those rats that were slower in returning to feed.

#### *Distribution of Rat Population:*

The detailed data on Experiment 1, Grove Farm Company, station by station, have been plotted on the map of the field shown in Fig. 19. The legends used are the same as those previously described for the Kilauea tests. By this method a graphic picture is presented of the distribution of the rats in the field in relation to natural cover occurring around the field.

The areas along the clean open pasture harbored comparatively few rats, as was also the case at Kilauea. There were 56 stations in various locations along the pasture and across the field on the ditchman's trail which were never visited during the entire period of the test (see Fig. 19). These areas were entirely free of rats. The rat population was unknown throughout some fairly large inside areas which were inaccessible at this stage of growth of the cane. According to the results from Kilauea we believe that most of the rats (not all) can be drawn greater distances to feeding stations than 100 feet or even 200 feet. In order to poison rats that have become established in unirrigated big cane, it would be necessary to provide access every 200 to 250 feet. However, this should not be necessary if the poison campaign were carried on early enough along the edges of permanent rat cover adjacent to fields of young cane.

An extremely heavy infestation of rats occurred along the gulches where the natural cover made the areas almost impenetrable. Bordering these areas there

were many distinct and clear-cut trails through the grass from the gulch into the cane. This was less pronounced at Grove Farm Company than in some locations at Kilauea. This map points out the areas of greatest rat population, and suggests that the early treatment of the adjacent cover, while the cane is small, would be the most effective and economical control.

#### *Unpoisoned Oats Following the Poisoned:*

After 8 days of poisoned, unpoisoned oats were again exposed for 5 days in all stations, to check upon the effectiveness of the poison. More than half of the stations had been visited in that 5-day period and oats consumed amounting to daily acceptance of 3 per cent per active station. This totalled 6.5 pounds for 5 days or an average of 1.3 pounds per day for the entire field (143 acres). These revisited stations were mostly along the gulch cover and indicated that either new emigrants were coming from the gulch or that some rats were able to detect the difference between poisoned and unpoisoned oats.

The number of rats could not have been large as one rat could do a lot of visiting and eating in a 5-day period; but it does indicate that the gulch areas must be poisoned thoroughly, as is recommended in detail in this article.

#### *Subsequent Treatment and Final Report on Field 23:*

W. P. Alexander, manager of Grove Farm Company, has reported that the field was poisoned again in June and harvested during August. He has kindly supplied us with data "on the rat population as indicated by the catch by dogs behind the harvesting gang." He states that "the following figures showing a relatively small number of rats per acre were confirmed by the observation that there was much less rat-eaten cane in this field which was badly damaged a year ago."

#### *Rats Caught by Dogs*

	Total	Per acre
Field 23 (143 acres), crop 1937 (15 months).....	408	2.9
Field 23, crop 1936 (22 months).....	1716	13.5
All fields—crop of 1936.....		12.0
To date—crop of 1937.....		10.1

These data offered by Mr. Alexander indicate a marked improvement in rat control which would have been more complete if certain areas had been accessible for treatment.

#### *Summary:*

This experiment was carried on during the period of April 9 to May 4th. The general plan of operation was the same as at Kilauea, but differed in that unpoisoned grain was exposed longer before the final poisoning, due to a slower acceptance by the rats. A very recent field poisoning with torpedoes had apparently made the remaining rats doubly cautious toward new food. However, the general results were the same as at Kilauea, but with a reduced efficiency. As at Kilauea, the rats were

most numerous along the gulch areas and wasteland where permanent cover is always present. The same suggested control measures—an early intensive campaign concentrated along the natural rat harbors adjacent to young cane—apply equally well to Grove Farm Company.

The final results of the rats caught at harvest show a greatly reduced population in this treated field compared with the previous (1936) crop and also to the rest of the fields for the present (1937) crop.

### CONCLUSIONS

1. The prebaited feeding-station method is effective and economical in poisoning rats in large field areas.
2. One round of poisoning may be made for as low as 30 cents per acre.
3. Six or more days of prebaiting with unpoisoned grain are necessary before poisoned grain should be substituted; the poisoned grain should remain in the field not less than 3 days.
4. Experimental work demonstrated that rats are most numerous and do the greatest damage along the edges of big cane bordering the heavy undergrowth of wastelands, particularly gulches and drains.
5. The prebaited feeding stations should be concentrated along the edges of young cane adjacent to natural rat cover or close to recently harvested fields.
6. We believe that if the area has been thoroughly and effectively covered the procedure need not be repeated for at least 3 months.
7. The success of this rat control method rests directly with the men in the field who are responsible for the intelligent distribution and handling of the feeding stations.
8. Curved galvanized iron covers placed over small square baking pans have proved to be the best feeding-station equipment.
9. Spacing between stations will vary with local conditions, but an average of four stations per acre should be sufficient for large field areas.
10. The approximate cost of station equipment is about 18 cents each. The cost for permanent equipment to serve 100 acres at 3-month intervals would be \$8.00.
11. Rolled oats are the most satisfactory bait which has been tested.
12. The sweetening of the poisoned bait is a definite benefit.
13. A concentration of thallium sulphate in the poisoned bait of one part in two hundred should be sufficient for the prebaited feeding stations.
14. The best attractants found thus far are corn oil, raw linseed oil, and coconut oil, in that order. One quart of oil is sufficient for 10-15 pounds of rolled oats.



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## Utilization of Molasses—II

PEN-FATTENING OF BEEF CATTLE ON MOLASSES AND  
OTHER BY-PRODUCT FEEDS  
(EXPERIMENT AT HAMAKUA MILL COMPANY)

By ALVIN R. LAMB

### INTRODUCTION

It has been previously noted by the writer\* that although about 80 per cent of the beef consumed in the Territory of Hawaii is locally produced, the remaining 20 per cent is imported from the mainland United States. This is used by the Army and Navy and by a group of other consumers who demand a certain quality which is generally obtained only by a final fattening period in small lots on concentrated rations. This system is called dry-lot feeding in the Middle West, to distinguish it from pasture feeding. We have chosen to use the term "pen-fattening," in order to make a definite distinction from fattening on grass pastures or paddocks, which commonly vary in size from 20 to 200 or more acres.

The size of the pens generally used is of the order of two thousand square feet for each 20 head of cattle. This amount of space is ample, but prevents much exercise, which is not desirable in the final stage of beef production. In this system of feeding, which produces most of the good beef marketed in the United States, the cattle make good gains over a three to four months' feeding period—provided they are not too fat at the outset—and become very tame and quiet, thus decreasing difficulty in handling and the losses due to bruising of the meat at marketing time. The muscles become softer and the meat thereby more tender, and the scattered deposition of fat in the muscle itself, which is described as "marbling," is considerably increased. This last factor makes a marked improvement in the market grade of the carcass and in the flavor of the cooked meat.

This system of feeding, using a ration including as much as possible of local by-products, has been tested in a steer-feeding experiment at the Hamakua Mill Company, Paauilo, Hawaii. The only previous experiment with this type of ration was conducted in 1928 at the Waianae Company, by Eremeef and Lennox.† They used a ration of molasses, bagasse and soybean oil meal substantially the same as that employed by Naquin in feeding mules at Honokaa‡ and their 10 steers gained an average of three pounds each per day over a period of 89 days. No data were shown on the quality of meat produced, but the value of the ration in producing good gains in feeder steers was conclusively demonstrated.

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\* Utilization of Molasses. The Use of Cane By-Products in Fattening Beef Cattle. The Hawaiian Planters' Record, 40: 121-125, 1936.

† Steer "Dry Lot" Fattening Experiment. The Hawaiian Planters' Record, 35: 341-344, 1931.

‡ Cane Pulp as a Carbonaceous Food for Animals. The Hawaiian Planters' Record, 33: 407-409, 1929.

Other systems of fattening beef under Hawaiian conditions, especially those which have been recently tested in cooperative experiments under the direction of the Hawaii Agricultural Experiment Station, will be discussed below. The adaptability of these various systems of feeding, which employ sugar cane by-products, to the various climatic and other conditions in the Territory, will also be discussed.

#### EXPERIMENTAL

Forty-seven head of two-year-old steers were selected at Kukaiau Ranch, with uniformity in type and conformation as the main considerations. The animals available were found to be in too high condition—i.e., too fat—to be economical feeders. Since, however, the chief purpose of the experiment was to compare the quality and finish of the beef produced on pasture with that produced by pen-feeding, these steers were considered as acceptable. The uniformity of the average gains in the three lots indicated, at the end of the experiment, that a fairly satisfactory degree of uniformity between the lots had been secured.

These steers were driven to the plantation (Hamakua Mill Company, Paauilo, Hawaii) and were weighed and eartagged. Each animal, as it was weighed, was graded on type, condition and temperament. They were then allotted very carefully, on paper, to three groups of 15 steers each, the three groups containing the nearest possible to an equal distribution in beef type, condition of fatness, weight, and quiet or nervous temperament. In order to eliminate any possible unconscious prejudice, these three groups were then assigned to pasture or pen-feeding by drawing lots. Lot 1 was assigned to the pasture and Lots 2 and 3 to pen-feeding.

The steers were weighed again on the two following days, to secure a true average initial weight. On the last day they were divided into their proper groups, and Lot 1 was driven to the pasture, a distance of about three-quarters of a mile.

The pasture available, at about 1500 feet elevation, contained approximately 80 acres for the group of 15 steers, plus the two extra steers which were kept with Lot 1. The forage in this pasture was estimated to be composed as follows: *Commelina nudiflora* (honohono) 5 per cent, *Tricholaena rosea* (Natal redtop) 20 per cent, *Cynodon dactylon* (Bermuda grass) 5 per cent, *Panicum barbinode* (Para grass) 5 per cent, *Paspalum digitatum* (Hilo grass) 40 per cent, *Desmodium uncinatum* (Spanish clover) 10 per cent, and various weeds and unidentified grasses, 15 per cent. Rain had been abundant and growth was excellent, and a good water supply was easily available to the steers.

Groups 2 and 3 were placed in corrals adjoining the mule-shed on the plantation. These lots were well shaded, and each contained about 1500 square feet, with the scale house and another small corral located between the two lots. Feed troughs were placed along the fence, and each lot was supplied with a water trough equipped with a constant-level intake valve. Each water trough was flushed out daily, and the feed troughs were cleaned and washed each morning before feeding. A general view of the feed troughs and scale house, and some of the cattle in Lot 3 are shown in Figs. 1 and 2.

The rations fed were as follows, with the nutrients calculated on the basis of average analyses:

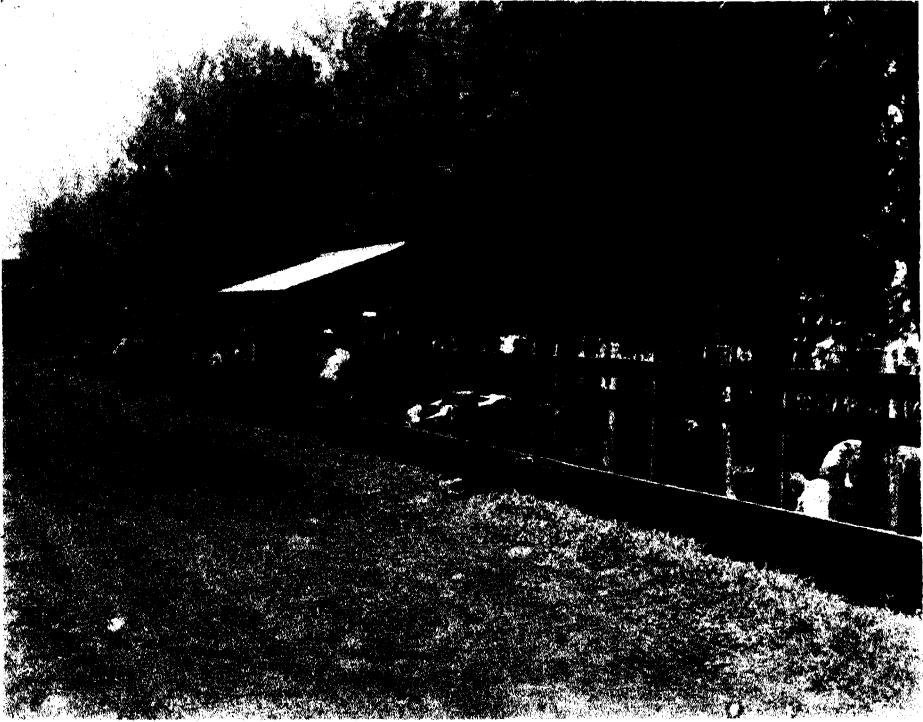


Fig. 1. Feed troughs and scale house. Roofs were later placed over the troughs to prevent serious washing of the feed by rain.



Fig. 2. Steers in Lot 3, after six weeks' feeding.



TABLE I  
COMPOSITION OF RATIONS

Lot 2			
	Total lb	Digestible crude protein lb	Total digestible nutrients lb
Screened bagasse .....	32	.25	16.00
Molasses .....	38	.35	22.80
Pineapple bran .....	12	.10	7.20
Soybean oil meal .....	16	6.25	13.60
Steamed bone meal .....	1	...	....
Salt .....	1	...	....
	<hr/> 100	<hr/> 6.95	<hr/> 59.60

Lot 3			
	Total lb	Digestible crude protein lb	Total digestible nutrients lb
Screened bagasse .....	24	.20	12.00
Molasses .....	38	.35	22.80
Pineapple bran .....	20	.16	12.00
Soybean oil meal .....	16	6.25	13.60
Steamed bone meal .....	1	...	....
Salt .....	1	...	....
	<hr/> 100	<hr/> 6.96	<hr/> 60.40

Four samples of these rations, taken at intervals of one week during the experiment, were chemically analyzed. The average analytical results are shown in Table II.

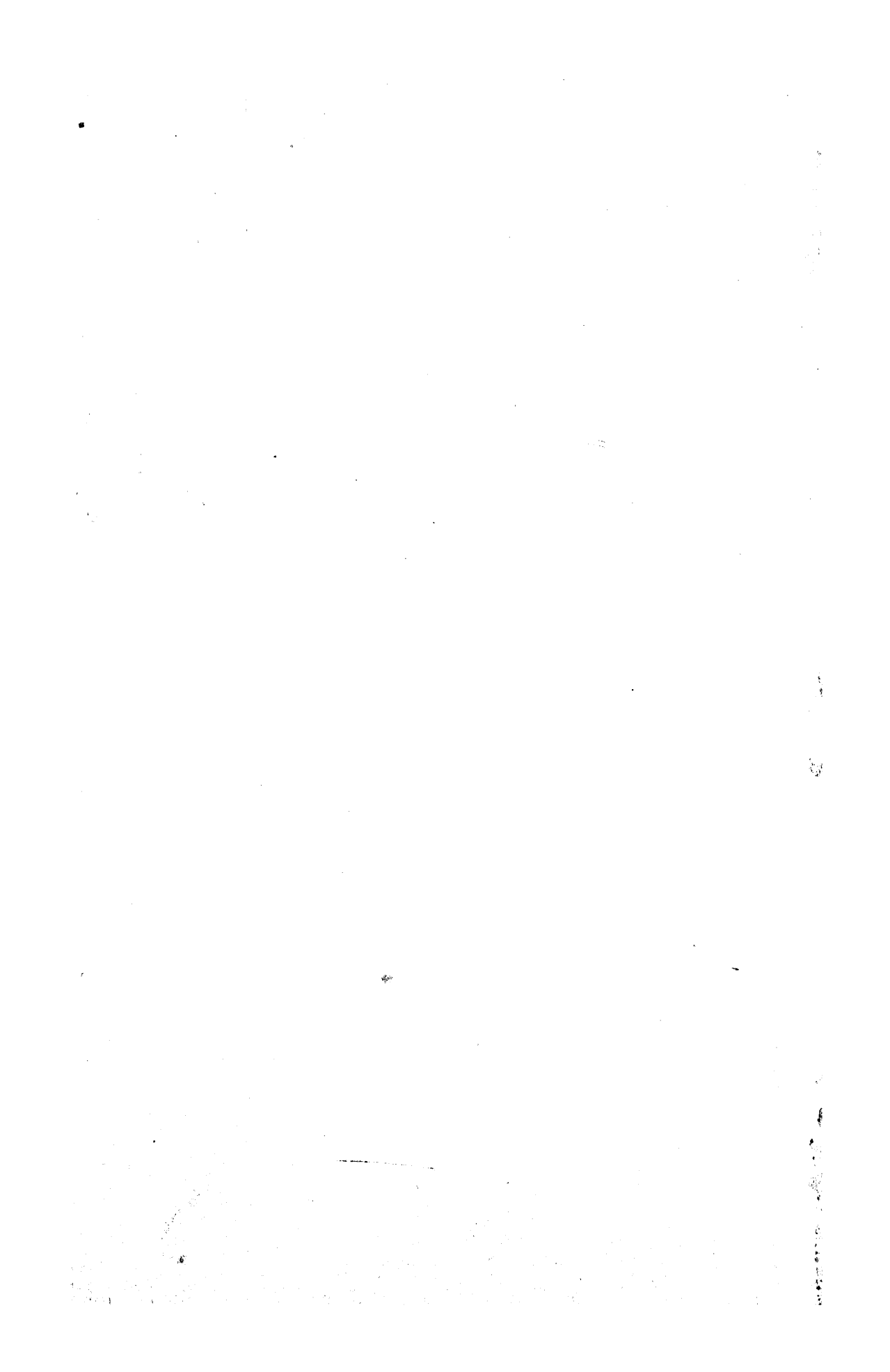
TABLE II  
ANALYSIS OF MIXED FEEDS

	Lot 2 %	Lot 3 %
Moisture in air-dry sample .....	5.67	5.77
Crude protein .....	11.42	11.83
Crude fat .....	2.43	2.65
Crude fiber .....	14.17	13.80
Ash .....	7.00	7.06
Nitrogen-free extract .....	59.31	58.89
	<hr/> 100.00	<hr/> 100.00

In addition to the above mixed ration, chopped cane tops were fed in an average amount of 10 pounds per steer per day. The nutritive ratios of these rations, including the cane tops, and calculated on the basis of the average feed consumption for the whole period, are 1:8.0 and 1:8.1 respectively.

The mixed ration was fed twice daily, early morning and afternoon, at a regular hour. About two hours later, when the mixed feed had been largely consumed, one-half of the day's allowance of chopped fresh cane tops was given. The steers found this very appetizing, and stayed at the feed trough until the feed was, on most days, all consumed.





At the beginning of the experiment the steers received cane tops only for the first two days. On the third day one pound of the molasses mixed feed was given for each animal. On the two following days three pounds were allowed per animal per day. This was increased thereafter at a rate of from one to three pounds per day, with a corresponding reduction in the amount of cane tops, until the allowance for each steer had reached 20 pounds per day, plus 10 pounds of cane tops. The amount of mixed feed was then gradually increased to a maximum of 29 pounds per day. The allowance of cane tops was decreased to five pounds per steer, but this was immediately thereafter increased to 10 pounds, which seemed to be the proper amount.

During the last three weeks of the experiment a change was made in the ration of Lot 2. The amount of bagasse was reduced to 18 per cent, and the pineapple bran increased to 26 per cent, to determine whether or not this mixture would be more appetizing, inducing a greater consumption of feed. Such a possible effect, however, during the short time indicated, was nullified by the somewhat disturbing effect of the change. Nevertheless it seems probable that the 32 per cent level is a little too high for bagasse, considering the factor of appetite. This is in accord with the observations of Professor Henke on dairy cattle.

The feed was given according to the appetite of the steers, allowing them all they would eat, decreasing the amount slightly if they left as much as 10 per cent. The average amount weighed back and discarded was, as shown in Table III, approximately 4.3 per cent. The feeding, which is a very important matter in economical beef production, was well done by the plantation herdsman, who had had considerable experience with dairy cattle, but had no previous experience with beef cattle. Observations on appetite, weather, and condition of the animals were carefully recorded throughout the experiment. A single steer was "off-feed" for a week early in the experiment. There was no case of "bloating" and no other similar trouble.

Factors which decreased the rate of gain were a certain amount of excitement at the monthly weigh day, and the amount of mud in the lots. The latter condition was much worse than anticipated, and it was necessary to disturb the animals considerably during a month or more by the hauling and distributing of a large amount of rock and gravel. This procedure seemed essential, although steers are not usually hampered in their gains by mud, if a reasonably dry area can be provided where they may lie down. There is no necessity for shelter in this climate, if part of the lot can be kept dry in rainy weather by having it properly graveled or concreted, at a slightly higher level than the rest of the lot.

Weighing the animals on three successive days was necessary in order to secure a nearly correct average initial weight, on account of the great variations in stomach and intestinal contents. This should also have been done at the end of the experiment, but it was so inconvenient to do so that only one final weight was taken. The average of the weights of 15 steers tends to smooth out some of this variation.

The monthly weights were necessary in order to judge the progress of the feeding. In ordinary feeding for market, not on an experimental basis, most of this weighing would be eliminated, and the removal of this considerable disturbance to the appetite of the animals would increase the gains.

The steers in Lot 1, pasture-fed, were not disturbed during the experiment, only the initial and final weights being taken.

## MARKETING AND GRADING THE BEEF

After a feeding period of 96 days, all three groups were weighed and marked with paint to insure correct identification of the carcasses. The steers were then shipped by rail to Hilo and by steamer to Honolulu, where they were slaughtered at the Hawaii Meat Company's plant. By the courtesy of this company, the writer was given every opportunity to check the identity of each animal as it was slaughtered, and to secure all the data desired on each carcass. The Federal officer in charge of meat inspection in Honolulu, Dr. L. Bilikam of the U. S. Bureau of Animal Industry, made a careful inspection of each carcass in the cooling room. Without knowing the experimental treatment of any carcass, he graded each one according to official government inspection standards, which consider mainly the quality, finish and conformation of the carcass. The significant results of this grading are shown with other data in Table III.

In making the above-described grading no attention was paid to bruises, which have no direct relation with the results of the feeding experiment. The purchaser, however, discounted each carcass showing ante-mortem bruises from one-fourth to one cent per pound. The effect of pen-feeding on the quietness and tameness of the steers is evidenced by the fact that five of the 15 pasture-fed steers showed bruising, while only one of the 30 pen-fed animals was bruised.

## DISCUSSION

A study of the detailed data in Table III brings out a number of important facts. It is probable that the care in allotting the animals and the fairly large number in each group make the averages a true picture of what was obtained under the conditions which existed in this experiment. The average gains, therefore, may be taken as showing what may be done with feeders as nearly ready for market as these were, disturbed as these were by several weighings and under unfavorable weather conditions.

The total gains, which were practically the same in all groups, were unsatisfactory. The rations fed, however, would produce much greater gains—as they have elsewhere—with thinner animals. Two of these steers gained 200 pounds each during the experiment, one of them having gained over four pounds per day during the first 30 days. A number of others put on approximately 150 pounds. Those which made small gains, such as numbers 63, 97, 69, 74, 59, 90, and 68, show by their yield of dressed carcass that they were already very fat. The average dressing percentage of these seven steers was 58.1 per cent, while the average of all the other pen-fed steers was 55.5 per cent.

A significant difference between the pasture-fed and pen-fed steers appears in the average dressing percentage by groups. Lot 1 averaged 54.9 per cent, and Lots 2 and 3 averaged 56.1 per cent and 56.2 per cent respectively.\* These figures show

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\* The standard deviation ("standard error") of the mean dressing percentage of the pasture-fed steers is 0.324 per cent. If Lots 2 and 3 are combined, the standard deviation of the mean dressing percentage of the group of 30 steers is 0.321 per cent. The difference between the mean dressing percentages of the pen-fed and pasture-fed steers (56.15—54.9) is 1.25, and the standard deviation of this difference is 0.456. The former is 2.74 times the latter, which figure corresponds with odds of 173 to 1 that this difference in dressing percentage is significant.

the relation of the weight of the dressed carcass to the live weight of the animal, and indicate a greater yield of marketable carcass from the pen-feeding. It may also be noted that the highest individual dressing percentage in the pasture-fed group was 57.1 per cent, while Lots 2 and 3 produced seven steers which exceeded this, one being as high as 60.1 per cent. This is unusually high, when it is considered that these animals received no feed for four days after the final live weights were taken, and before they were slaughtered.

The most important data bearing on the results obtained by pen-feeding in contrast to pasture-fattening appear in the carcass grades shown in Table III. As previously stated, the steers were allotted as evenly as possible at the beginning of the experiment with particular attention to beef type, conformation and condition. Nevertheless, in the pasture-fed group the carcasses rated 3 good, 11 medium, and one common. The two pen-fed groups produced 7 good, 8 medium; and 8 good, 7 medium carcasses respectively. This is apparently due to the fat having been better and more evenly distributed, as well as to the tendency to favor the deposition of fat instead of the growth of muscle tissue under the conditions of pen-feeding. The price per pound paid by the purchaser for these carcasses, which depends somewhat on the total weight as well as on the quality and condition of the carcass, was in most cases correlated with Dr. Bilikam's grading although entirely independent of it. These prices are also shown in Table III.

Unfortunately it was not possible to make controlled comparative tests on the quality and flavor of the meat when cooked. Several cuts of representative carcasses, however, from both control and pen-fed animals, were cooked by the writer under comparable conditions. The difference in juiciness and flavor, apparently referable to the extent of "marbling," was definitely in favor of the pen-fed carcasses. The Army and Navy officers who are actively engaged at present in inspecting meats for all the service units in Hawaii saw several representative carcasses and stated that they were at least as good as the beef which is currently imported from the mainland.

The illustrations of cuts from some of these carcasses (Figs. 3 and 4) show plainly the difference in marbling, or deposition of fat between the bundles of muscle fibers. The tendency to deposit fat in these locations comes naturally in a fairly well-fed steer about three years old or more, and is increased, as well as brought about at an earlier age, by the conditions of pen-feeding. In fattening beef animals this type of fat deposition is greatly preferred as it lessens the waste due to the accumulation of large masses of fat external to the muscles and in the abdominal cavity. The factor of waste as well as the improvement in quality and flavor of the meat from properly marbled carcasses lead to discrimination by buyers in favor of this type of carcass if prices are comparable, or to the paying of a higher price in a well-established market.

The deposition of fat, in any location, is the most expensive part of the process of beef production. This is on account of the fact that fat contains 2.25 times as much energy as carbohydrate or protein. The amount of extra feed which would deposit one pound of fat would be enough for 2.25 pounds of body protein, besides the weight of the amount of water which is a normal part of muscle tissue, but not of fat. This tendency of animals to deposit more fat and less protein in the later

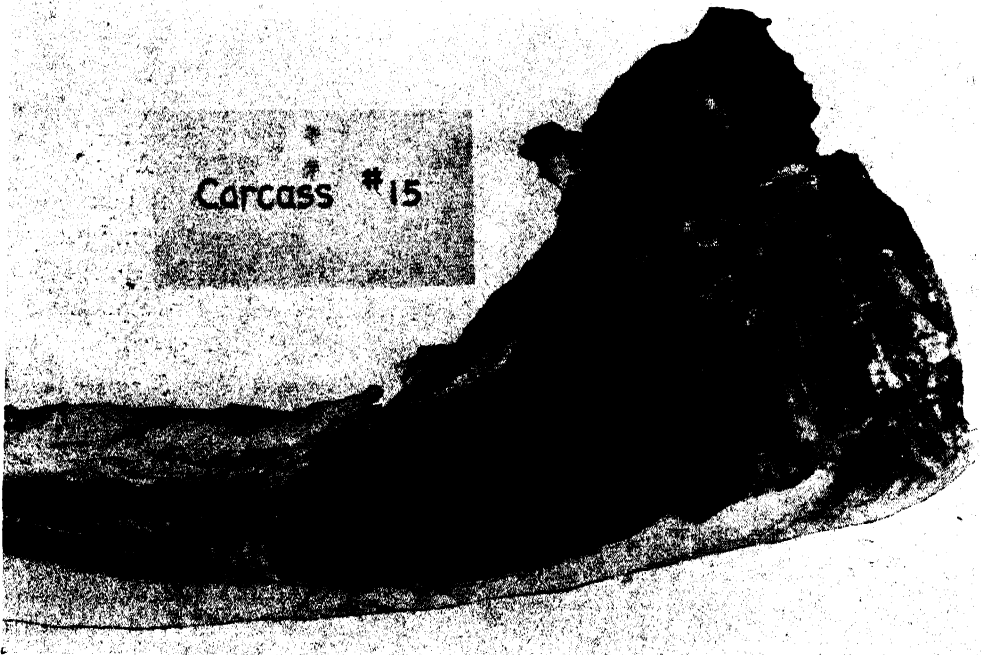
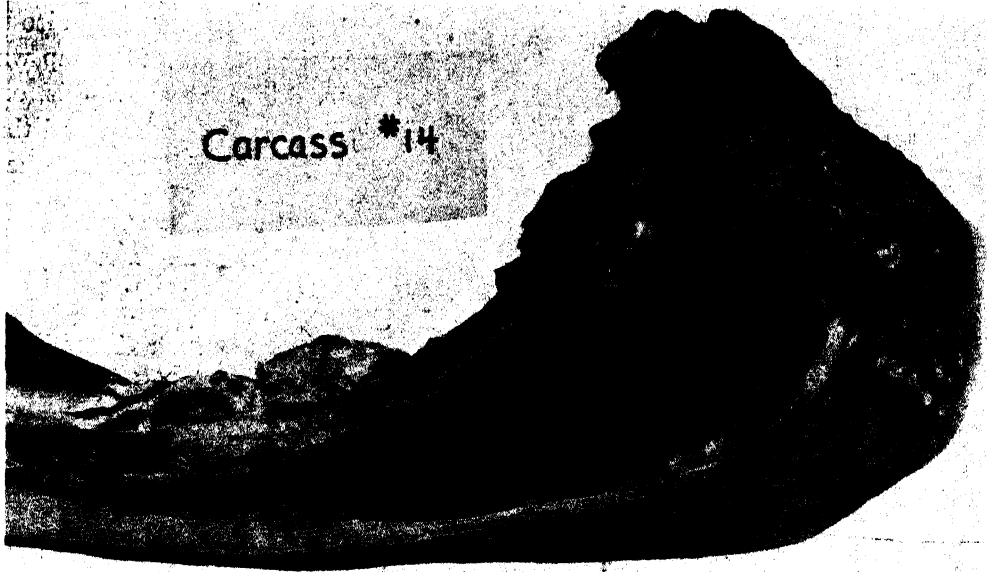


Fig. 3. Cross-sections of loin at "first" rib, from two of the best pasture-fed steers. (These are not quite typical of Lot 1, since No. 14 rated "Good," and No. 15 "Good—." They were the only carcasses from this lot available for photography. No. 14 is one of the two extra steers brought down from the ranch, not included in the data, but which were carried along with Lot 1 on pasture. Final live weight of this steer was 1135 pounds.)

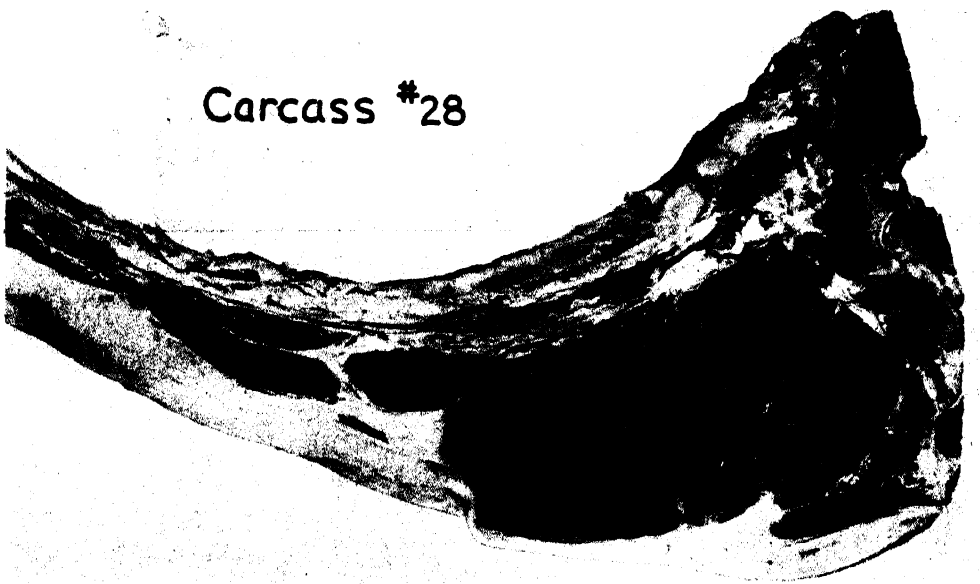


Fig. 4. Cuts from the same location as those shown in Fig. 3. No. 5, from Lot 2, rated "Good," and No. 28, from Lot 3, rated "Good—." Note the marbling, in comparison with Lot 1.



stages of fattening is well shown by the work of Trowbridge, Moulton and Haigh.\* A typical comparison from their careful and extensive work on this subject indicates that the first 500 pounds gain of a young steer consisted of fat 46 per cent, protein 12 per cent, water 40 per cent. The second 500 pounds gain, bringing the steer to a prime condition, consisted of fat 68 per cent, protein 6.6 per cent, water 22 per cent. It is this and the high energy content of fat which make the later gains the most expensive, as well as the most valuable to the consumer. This also shows why it is necessary for profitable feeding, to start the fattening process with thinner or younger animals than was done in this experiment.

Another necessity is the use of cheap feeds. This can be met on the plantation by the use of molasses, bagasse and cane tops for the greater part of the ration. Further possibilities for cheapening the cost of the ration are in the growth of protein crops, the production of yeast protein from molasses, and the use of fish meal locally produced to avoid the importation of protein feeds.

Steers may be taken from a good range at an earlier age than was done in this experiment, but not too young, as their growth requirements would then necessitate too high a proportion of the more expensive protein feeds in the ration. It is probable that steers could be started on pen-feeding at six months younger than the animals in this experiment, if taken from a range of comparable quality and rainfall. Further comparison of the results from fattening cattle at different ages would give definite data on this point.

Other systems of fattening will give excellent results under proper conditions. The feeding practices in this Territory will undoubtedly develop in the direction of variable or elastic plans based on climatic or other local conditions. It seems probable that on range areas which are often short in rainfall and in which cattle have to travel considerable distances to secure their feed it will be found profitable to depend more on pen-fattening to finish the cattle. Other ranges which are fortunate enough to have lush pastures, at least in years of good rainfall, may find it preferable to finish their cattle on grass in relatively small paddocks, feeding molasses in tanks as a supplement, which will reduce the amount of exercise necessary for the cattle to secure the necessary feed intake. Some cattlemen who are using this plan are also feeding some protein supplement in the molasses. This plan probably will produce the cheapest gains, but will not usually produce a high percentage of good carcasses which will meet the demands of those who are now importing beef. That particular market seems to be open to those beef producers who are in a position to use cheap cane by-products for feed. The extent of that market was discussed in the first paper of this series.†

### FEEDING COSTS

In Table IV is presented a balance sheet showing the actual costs of this experiment. The steers were bought on the basis of the Honolulu price for the dressed carcass. The weight of dressed carcass was calculated from the live weight of the

\* Composition of the Beef Animal and Energy Cost of Fattening. Missouri Agr. Expt. Stn. Res. Bul. 30, 106 pages, 1919.

† Utilization of Molasses. The Use of Cane By-Products in Fattening Beef Cattle. The Hawaiian Planters' Record, 40: 121-125, 1936.

steers as purchased by multiplying by the factor 0.55, which is the yield of carcass shown by the pasture-fed group when marketed. Variations in market price are eliminated by using for the cost price the price obtained for the pasture-fed steers at the time of marketing the cattle. Using the price of finished cattle for the initial cost may be appropriate in this case, as the steers were so nearly finished. Normal "feeders" in thinner condition should be bought at an appreciably lower price. In the latter case, with no great change in market price, there would normally be some profit in the price per pound of finished cattle, in addition to the return from the increase in weight.

TABLE IV  
BALANCE SHEET

Debit		Credit
Cost of 45 head steers* .....	\$4,269.60	Cash received:
Overhead costs:		Lot 1—15 head at 17.98¢.....
Lumber, etc. for lots..	\$276.60	Lot 2—15 head at 18.20¢.....
Labor, construction and		Lot 3—15 head at 18.22¢.....
graveling .....	602.65	
	<hr/>	
	\$879.25	
One-tenth of overhead construc-		
tion costs .....	87.93	
Labor—feeding and care .....	103.50	
Feed—imported .....	390.67	
Feed—local† .....	99.65	Loss .....
	<hr/>	
	\$4,951.35	<hr/>
		\$4,951.35

\* At 18 cents per pound of carcass, based on first day's weights.

Estimated dressed weight, 55 per cent of live weight.

† Molasses, 12.75 tons at \$4.00.

Cane tops, 15.275 tons at \$2.00.

Bagasse, 9.05 tons at \$2.00.

Since the price paid for these cattle was based on the price of the carcasses delivered in Honolulu, the freight was paid by the ranch, and does not appear as such in Table IV.

The costs of construction of the feed lots, fences, scale house, etc., including the cost of putting in the gravel and rock during the experiment, are considered as overhead, and the amount charged against this single feeding operation is 10 per cent.

The cost of the imported protein feed was the greatest item in expense, and could be much reduced in practice by local production of protein feeds as suggested in the discussion above. These observations indicate the possibility of changing the loss shown here to a good profit, if changes in procedure suggested by this experiment are adopted. Thinner cattle of proper feeder type which would gain at the rate of two pounds or more per day, could be bought at a price lower than that paid for fat cattle. This would still be profitable to the rancher, for it would take the cattle from the range at an earlier age, leaving room for more calves on the same area and increasing the annual output of beef without much increase in the overhead costs of the ranch. This increased output would be the amount necessary to supply the beef

now imported from the mainland, and would go to that 20 per cent of the local consumers who now buy imported beef.

It is well within the abilities of the ranches of the Territory to supply this increased amount of beef, in animals of very good breeding, of quality such that this particular consumer demand would be easily satisfied when the cattle are finished as desired by these consumers. This experiment therefore furnishes an indication of a possible system of beef production, an additional benefit of which would be a cash return from the cane by-products, bagasse, cane tops and molasses.

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## Utilization of Molasses—III

FEEDING TRIALS ON LABORATORY ANIMALS TO DETERMINE THE VALUE OF  
BAGASSE, MOLASSES, AND KIAWE BEAN MEAL

By ALVIN R. LAMB

It has long been the practice of stockmen to feed large amounts of wheat and oat straw, corn stover (dry stalks) and similar fibrous plant residues to animals which were merely being maintained over winter. It has thus been conclusively demonstrated that horses and cattle can derive considerable nourishment from such materials. It is well known that an appreciable amount of energy comes from the products of fermentation of such fibrous feeds in the paunch of ruminants and in the cecum of horses and mules. Dried bagasse, a material similar to corn stalks, has been used since 1927 by W. P. Naquin, at Honokaa Sugar Company, as 40 per cent of his regular ration for the plantation mules.\* In this ration the bagasse is mixed with an equal amount of molasses (40 per cent of the total mixture) and with soybean oil meal (20 per cent) which supplies the necessary protein.

### BAGASSE EXPERIMENT

In order to secure more definite data on the actual value of bagasse under controlled conditions, an experiment using rabbits as subjects was started in July 1935. The rabbit is a herbivorous animal with an alimentary tract very similar in anatomy and function to that of the horse or mule, and is in that respect an excellent laboratory animal for such an experiment. In order to make the experimental conditions more nearly comparable with those of work animals the rabbits were exercised daily except Sunday in a machine (Fig. 1) which was rotated by an electric motor at such a rate that the animals traveled somewhat leisurely at a rate of 1,680 feet per hour. The amount of this exercise during the experiment will be given later.

The rations fed were as follows:

Group A-1 (control)	%	Group A-2	%
Alfalfa meal .....	50	Bagasse (sifted) .....	55
Rolled barley .....	25	Molasses .....	26.5
Molasses .....	25	Soybean oil meal .....	18.5
	<hr/> 100		<hr/> 100

These rations yield 8.0 per cent of digestible crude protein, with a nutritive ratio of 1:6.8.

Four young rabbits, females and litter mates, were taken at an average weight of 930 grams, two rabbits to each group. All received the control ration for the first 30 days, after which Group A-2 was gradually started on the bagasse ration.

\* Cane Pulp as a Carbonaceous Food for Animals. *The Hawaiian Planters' Record*, 33: 407-409, 1929.

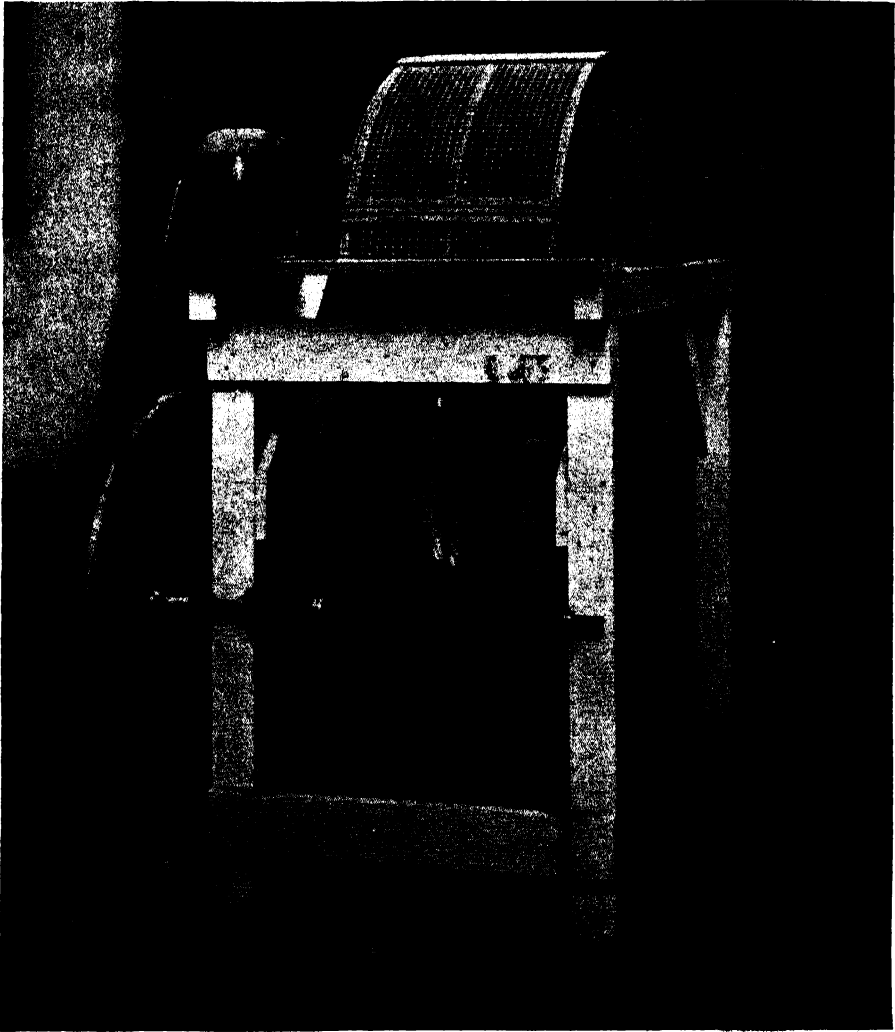


Fig. 1. Exercising machine run by electric motor. Rate of rotation, 3 r.p.m.

During the next 10 weeks the amount of bagasse ration was increased and the control ration was gradually reduced to zero, after which time 25 grams of fresh cane tops were fed daily to each rabbit in Group A-2. It was anticipated that young rabbits would not secure enough nutrients from this experimental ration to make approximately normal growth unless some natural feed such as alfalfa were given during the first part of the growing period. This was the reason for the gradual withdrawal of the control ration. After the rabbits reached an average weight of 1700 grams, no more control ration was given, but the cane tops were given, as stated above, throughout the remaining 23 months of the experiment. It was apparently necessary to give this small amount of green feed to keep the animals in normal health. The amount of energy contributed by the green cane tops, however, was very small.

The average daily net feed consumption for the whole experiment was as follows :

Group A-1—150 grams.

Group A-2—159 grams, plus 23 grams cane tops.

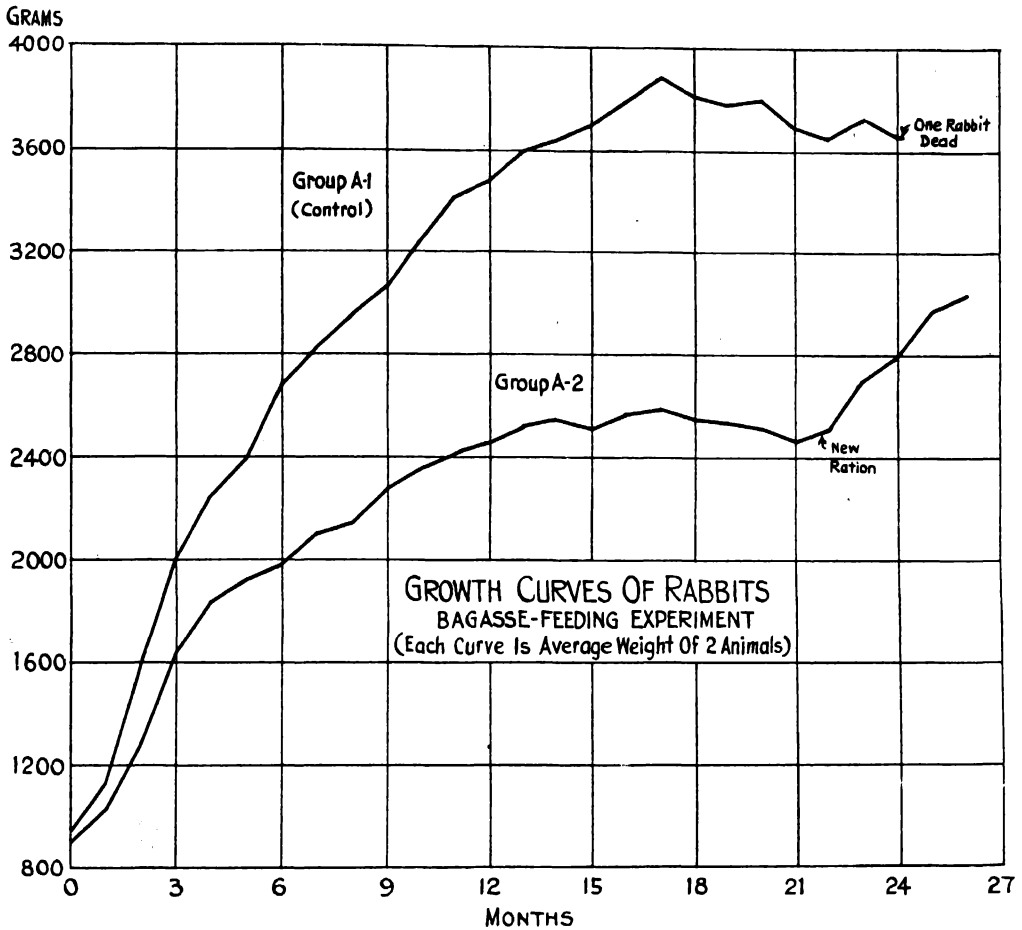


Fig. 2.

The figure for the bagasse group is higher than their actual consumption, on account of the physical character of this mixture. Although it was fed from hanging dishes, a considerable amount was scattered and lost in the litter.

Throughout the preliminary period the rabbits were being trained to exercise properly in the machine. This was quite a difficult process, but after the first two months they were exercising one hour per day, which rate was maintained for about one month. For the next seven months thereafter they exercised two hours daily, and for the next 10 months each received approximately two and one-half hours. It was obvious during most of this time that the bagasse rabbits, although they had not grown nearly as large nor as fat as the controls (see Fig. 2), were still quite fresh after the day's exercise, while the controls were usually tired and panting after the same amount of exercise. During the next two weeks, therefore, the controls received two and one-half hours exercise and the bagasse rabbits three hours. For four weeks thereafter the controls were given three hours and the bagasse animals three and one-half hours, with the latter still able to continue longer. The exercise was always given in one-hour periods or less.

Up to this time the experimental animals had received only the mixture which contained 55 per cent of bagasse, plus a small amount of cane tops, for a period of 18 months, and had done a considerable amount of work, the same amount or more

than the controls. This was apparently a demonstration that a considerable amount of energy had been metabolized from the bagasse, since these animals could not do this amount of work while continuing to gain weight, even slowly, on less than half the food intake (other than bagasse) of the controls.

A ration containing this large amount of bagasse (55 per cent) is, however, impractical. It was used only to give some information on the extent to which the bagasse may be utilized. The ration was changed at this point, therefore, to one which is suitable for plantation work animals, and which has been recommended for that purpose. At the same time the proportions of the control ration were also changed so that it would give the same proportions of nutrients, the nutritive ratios of the new rations shown below being 1:8.0.

Group A-1		Group A-2	
	%		%
Alfalfa meal .....	45	Bagasse (sifted) .....	33.3
Rolled barley .....	20	Pineapple bran .....	16.7
Molasses .....	35	Soybean oil meal .....	16.7
	<hr/>	Molasses .....	33.3
	100		<hr/>
			100
		Plus cane tops, 50 grams per rabbit per day.	

It may be easily seen from the curve in Fig. 2 that the new ration was much more efficient, as the animals immediately began to gain weight and continued to do so until the experiment was discontinued. The exercise was continued at the rate of about three hours each daily during the next two and one-half months, except that during one month of this time the bagasse rabbits received one-half hour more than the controls. At this time one control animal died, showing post-mortem evidence of intestinal obstruction. The other animal in this group appeared to be sick at this time, but quickly recovered. For the last one and one-half months of the experiment this control animal received two hours exercise and the experimental animals three hours.

The experiment was terminated on September 8, 1937, and the rabbits were killed. All were in good condition, with the skin, fur, muscle tissue, and visceral organs all macroscopically normal. Fig. 3 shows the appearance of these animals one week before the end of the experiment, which had continued over a period of two-thirds of the normal life span of the rabbit.

#### KIAWE BEAN FEEDING EXPERIMENT

The extensive use of kiawe bean pods (from *Prosopis Chilensis*) for feeding livestock in many parts of the Territory has brought them into consideration as a possible part of rations utilizing our waste molasses, bagasse, and other by-products. There has been no previous information as to the nutritional value of the proteins of these pods, and some doubt has existed as to possible unfavorable effects from

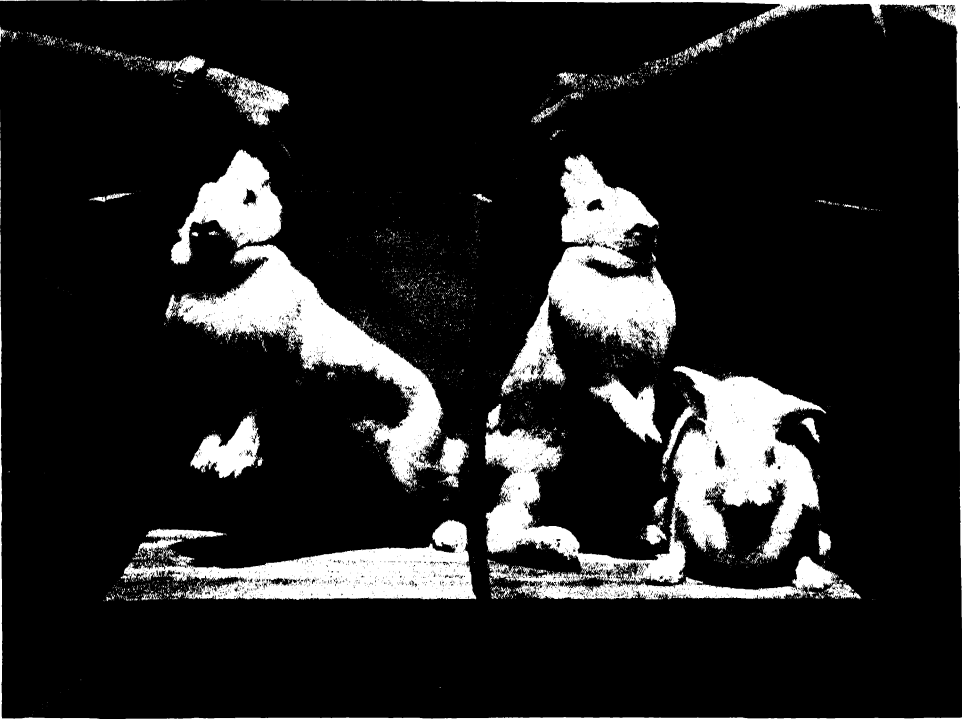


Fig. 3. At end of bagasse-feeding experiment. Control rabbit at left, two bagasse-fed rabbits at right.

feeding them in considerable amounts over extended periods. The Hawaii Agricultural Experiment Station has determined\* the digestibility of the meal made from this material, and has used it as a part of hog and dairy-cow rations. In order to determine the protein value and the possible toxicity, however, a different sort of test, usually over a considerable part of the life cycle of small laboratory animals, is necessary. An experiment of this sort on a small scale has been carried on.

Five rabbits, litter mates, about eight weeks of age, were divided into three groups. The rations fed were as follows:

	Group B-1 (2 animals)	Group B-2 (2 animals)	Group B-3 (1 animal)
	%	%	%
Kiawe bean meal .....	99	90	30
Soybean oil meal .....	—	9	20
Molasses .....	—	—	21
Screened bagasse .....	—	—	28
Steamed bone meal .....	0.5	0.5	0.5
Common salt .....	0.5	0.5	0.5
	100	100	100

\* Henke, L. A., and Work, S. H. Personal communications.



Representative samples of the kiawe bean meal used (from Hawaiian Commercial and Sugar Company, Puunene, Maui) have been chemically analyzed at the Station, showing the composition of the air-dry meal to be as follows:

	Moisture %	Crude fat %	Crude fiber %	Crude protein %	Nitrogen- free extract %
1935 crop .....	3.07	1.94	21.68	10.81	62.5
1936 crop .....	3.61	1.81	19.02	10.35	65.2

Vitamin additions were supplied to these rations in the form of one haliver oil capsule (three drops) and one-half of one "Rexall" dried compressed yeast tablet per animal. These materials were given twice weekly for the first ten weeks, and six times per week thereafter. This was planned to provide the necessary vitamin supplements in abundance, the mineral supplements necessary being also supplied equally to all three groups, in the form of bone meal and salt. Thus, the only probable deficiency in the first ration would be in the quality and amount of the protein. Unfavorable results might also be due, in the case of Group B-1, to some unfavorable or even toxic constituent in the meal.

In Group B-2, an increase in the protein content of the ration was made by adding 9 per cent of soybean oil meal, which contains over 40 per cent of protein of high quality. This was designed to furnish an abundance of a good protein supplement, leaving as the only factors which might affect the growth of the animals, a possible deleterious substance in the kiawe bean or a failure to consume enough of the ration.

In Group B-3 the ration included only 30 per cent of the factor under consideration, in combination with soybean meal and sugar cane by-products, to show the comparative value of a suitable local by-product ration including an amount of kiawe bean meal which seemed satisfactory for the practical feeding of plantation animals.

As is shown clearly in the accompanying curves (Fig. 4), this third ration was the most satisfactory. The second group (B-2) gained much better than Group B-1, indicating that the proteins of the kiawe bean meal are not complete enough to be satisfactory at a 10 per cent protein level, and are therefore improved by the addition of a protein supplement. The growth curve of Group B-2, however, is not as good as that of Group B-3, which may be due either to a failure to consume enough of the highly flavored feed, which might eventually become unappetizing, or to something unfavorable in the kiawe bean which had a slight effect on growth or appetite. Both of these possibilities would be related to the high content of kiawe bean (90 per cent) in the ration.

The sub-normal growth of Group B-1, (99 per cent kiawe bean) and their slightly rough-coated appearance, would be sufficiently explained by the protein deficiency, although other unfavorable factors could play some part. As would be expected, there was little or no attempt at mating in this cage, although Group B-2, on a better protein diet, was apparently normal. There was no reproduction, however, in this group.

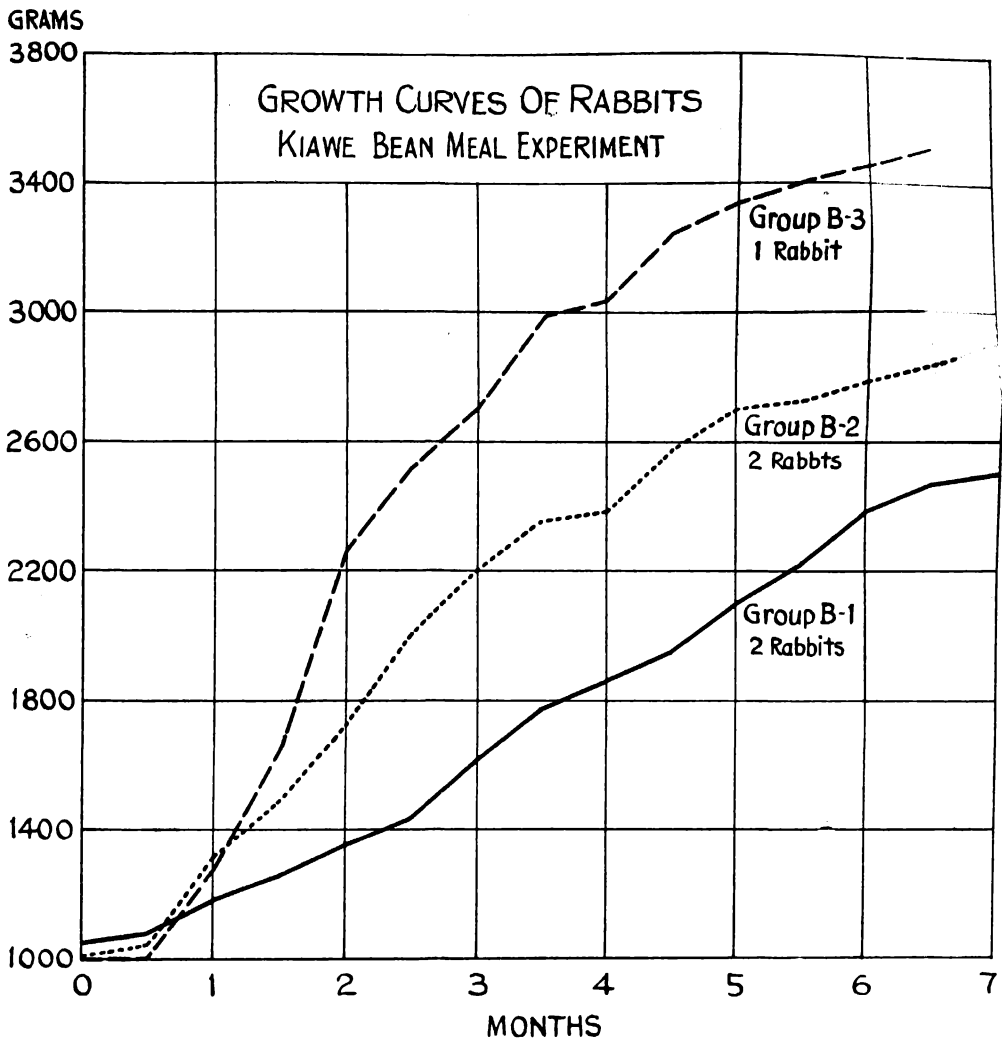


Fig. 4.

The average net feed eaten by these rabbits, including of necessity some waste, was as follows:

- Group B-1—145 grams daily per animal.
- Group B-2—142 grams daily per animal.
- Group B-3—162 grams daily per animal.

#### DISCUSSION

Using growing rabbits, the protein value of kiawe bean meal has been found to be somewhat less than optimum. Two animals receiving kiawe bean meal only (plus vitamin and mineral supplements) reached an average weight of 2500 grams in 7 months. When 9 per cent soybean oil meal was added to the ration, litter mates reached an average weight of 2900 grams. When 30 per cent kiawe bean meal was included in a ration of soybean oil meal, bagasse, and molasses, the single animal (litter mate of the others) on this ration weighed 3500 grams at the same time. This indicates that while kiawe bean proteins are not of optimum value, the material is

quite valuable as a part of the ration for these animals, and presumably for any herbivorous animal.

Kiawe bean pods are produced over large areas of waste land in this Territory. When dried they can be ground into a meal which is very palatable to livestock. As a part of by-product rations, including such materials as bagasse, cane tops, pineapple bran, rice bran, and molasses, they would contribute to the efficiency of such feed mixtures, and might well be used in greater amounts than at present. This would help to increase the efficiency of such feed mixtures, reduce the importation of feeds, and thus increase the use of our most important by-product, which is molasses.

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## Sugar Prices

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96° Centrifugals for the Period  
September 16, 1937 to December 9, 1937

Date		Per Pound	Per Ton	Remarks
Sept. 16, 1937..		3.42875¢	\$68.58	Philippines, 3.40; Cubas, 3.405 and Puerto Ricos, 3.48.
“ 22 .....		3.33	66.60	Cubas.
“ 23 .....		3.315	66.30	Puerto Ricos, 3.33; Cubas, 3.30.
“ 27 .....		3.25	65.00	Puerto Ricos.
“ 28 .....		3.20	64.00	Cubas.
Oct. 6 .....		3.15	63.00	Cubas.
“ 21 .....		3.20	64.00	Cubas.
“ 27 .....		3.17	63.40	Philippines.
“ 29 .....		3.235	64.70	Cubas, 3.22; Puerto Ricos, 3.25.
“ 29 .....		3.2333	64.67	Cubas, 3.22; Puerto Ricos, 3.23, 3.25.
Nov. 3 .....		3.22	64.40	Philippines.
“ 5 .....		3.2333	64.67	Cubas, 3.22, 3.25; Puerto Ricos, 3.23.
“ 9 .....		3.25	65.00	Cubas, Puerto Ricos, Philippines.
“ 10 .....		3.31	66.20	Cubas, 3.30; Philippines, 3.32.
“ 12 .....		3.34	66.80	Puerto Ricos, Cubas, 3.33; Cubas, 3.35.
“ 16 .....		3.32	66.40	Cubas.
“ 18 .....		3.3767	67.53	Cubas, 3.35; Puerto Ricos, 3.38, 3.40.
“ 19 .....		3.45	69.00	Puerto Ricos.
“ 27 .....		3.30	66.00	Cubas.
Dec. 3 .....		3.35	67.00	Puerto Ricos.
“ 6 .....		3.30	66.00	Puerto Ricos.
“ 7 .....		3.28	65.60	Cubas.
“ 9 .....		3.20	64.00	Puerto Ricos.

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# THE HAWAIIAN PLANTERS' RECORD

Vol. XLII

SECOND QUARTER 1938

No. 2

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*A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.*

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## **In This Issue:**

### *Weevil Damage to Stored Rice in Hawaii:*

Tests have shown unhusked or paddy rice to be highly resistant to rice weevil and other insect injury, as compared with the husked product, both polished and unpolished. In the event of periods of emergency in Hawaii when large quantities of imported or locally grown rice might be held in storage, deterioration would be least in rice held in the unhusked or paddy state.

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### *A Refinement in the R.C.M. Determination of Phosphate in Soil:*

A modified method is submitted for the determination of phosphate in soil in which a more accurate result is rendered possible by eliminating in the analytical process a number of interfering substances which may appear in the soil extract.

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### *A Grass Mealybug Occurring on Sugar Cane:*

An interesting and rare case of the grass mealybug *Antonina indica* occurring on Lahaina cane in culture pots at the Experiment Station is discussed and illustrated.

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### *A Bufo Marinus of Exceptional Size:*

A toad was recently found in Honolulu of such unusually large proportions that it is figured and described.

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### *The Plant Food Value of Nitrogen in Filter Cake:*

Repeated investigation of the plant food value of the nitrogen contained in filter cake continues to give the same answer—we are unable to secure measurable gains from, or to place any real food value on this nitrogen.

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*The Analysis of Plant Material for Total Nitrogen, Phosphate and Potash—  
An Improved and Simplified R.C.M. Procedure:*

Nitrogen studies in the sugar cane plant by plantation and Experiment Station staffs have shown the value of the moisture in the specimen in making correlation comparisons.

The important relationships of potash and phosphate with the nitrogen fraction of plant materials have stimulated the development of an efficient R.C.M. procedure to make these determinations which may be used with a decided saving of time without a sacrifice of analytical accuracy.

A modified procedure is submitted which, it is believed, will embrace all of these desirable features.

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*Some Sugar Yield Relationships:*

Studies of the effect upon sugar yields of such factors as the number of ratoons between successive plantings, of the month of starting and of harvesting the crop, and of the age of the crop at harvest, have indicated some rather definite relationships, which are shown from crop data from Waialua Agricultural Company, Ltd.

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*Stem Galls of Sugar Cane Induced With an Insect Extract:*

The development of stem galls on cane stalks which were inoculated with an extract prepared by macerating green leafhoppers is described and illustrated. A brief discussion on auxins or growth-promoting substances which may induce stem galls is given.

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*The Giant African Snail Achatina fulica (Fér.) Discovered in Hawaii:*

A giant African snail, notorious as a pest of vegetables and ornamentals in India, Ceylon, Malaya, Java and Borneo where it has been introduced, has been discovered in the possession of eight different residents of Hawaii during April and May, 1938. Two lots were found on Maui and the remainder in Honolulu. They are all apparently the progeny of two introductions, totaling 10 snails, brought in by two residents in 1936. A discussion of its history and destructiveness is given.

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*Defining Colloidal Solutions:*

In a paper presented at a meeting of the Hawaiian Section of the American Chemical Society, a brief discussion is given of some properties of colloidal solutions. Attention is called to similarities between these and true solutions.

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*The Introduction Into Hawaii From Mexico of Insect Parasites to  
Control Armyworms (1923-1924):*

This article gives an account of work in Mexico by H. T. Osborn in connection with introduction of parasites for armyworms. This resulted in the establishment of two very valuable parasites—*Euplectrus platyhyphenae* and *Archytas cirphis*—

which in about a year became established and soon spread throughout the Islands, and now render considerable assistance in the general control of armyworms. Other parasites were studied, the introduction of which was not successful. At the present time, with airplane service, it should be possible to introduce more of these parasites.

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*Introduction Into the Hawaiian Islands of Mexican Enemies of the  
Avocado Mealybug:*

This article is an account by H. T. Osborn of his work in Mexico in 1922 in connection with the introduction into Hawaii of enemies of the avocado mealybug. The most important introduction was the little internal parasite *Pseudaphycus utilis*, which quickly became established and spread throughout the Islands, and is responsible for the continuous absence, since then, of any mealybug infestations on avocado trees.

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## Susceptibility of Unhusked Rice (Paddy) Versus Polished Rice to Rice Weevil Attack

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By C. E. PEMBERTON

Stored, polished rice is subject to rapid destruction in Hawaii by certain insects, unless specially treated and then stored in clean, tight containers. Unhusked rice or paddy, although susceptible to attack by the same insects, becomes damaged very slowly. Even husked but unpolished rice shows a marked resistance to insect attack, as compared with polished rice.

A test, comparing the relative resistance of unhusked rice, husked but unpolished rice, and polished rice to rice weevil (*Calendra oryzae*) attack, was begun September 29, 1937, and completed January 14, 1938. The three lots of rice were treated as follows:

1. One hundred rice weevils were placed in a large glass jar containing three quarts of sound, polished California rice.
2. One hundred rice weevils were placed in a large glass jar containing four quarts of sound, husked but unpolished California rice.
3. One hundred rice weevils were placed in a large glass jar containing five quarts of sound, unhusked California rice (paddy).

Each of the jars was covered with a strong cloth to prevent the escape of weevils and placed in a dark room. One hundred and seven days later the jars were fumigated and the contents examined. The condition of the rice and the extent of weevil development in each lot are shown in the following tabulation:

Lot No.	Rice tested	Per cent sound grains	Number of weevils per quart of grain
1	Husked and polished	0.0	14,828
2	Husked and unpolished	76.0	1,488
3	Unhusked (paddy)	97.5	176

The test was instituted through the suggestion and help of W. J. Hartung, Executive Secretary, Diversified Crops Committee, H.S.P.A., and has bearing on the problem of rice storage in quantity during emergency periods in Hawaii.

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# A Refinement in the R.C.M. Determination of Phosphate in Soil\*

By FRANCIS E. HANCE

This modification in analytical procedure, when substituted for that now in use, does not detract from correlation values already considered or from those to be determined. The refinement is a development resulting from research which has been in progress for some time on all R.C.M. procedures and which will continue in the future. The magnitude of correction in soil phosphate values with most soils, of course, will be found insignificant. In such cases the modification may be disregarded. However, the simplicity of the revised procedure renders the checking of the point a very easy and inexpensive matter. Interference with the estimation of phosphate in soil as occasioned by the presence of calcium, silicates, nitrates, carbonates, ferrous iron, or traces of selenium, arsenic, titanium, aluminum, or manganese are **eliminated** in this simple analytical revision.

A number of common or of rarer soil constituents, which may or may not be present in any given soil, react in the phosphate determination in a manner which fictitiously increases the final reading to a variable degree. To insure greater accuracy, it is recommended that the following modification of the R.C.M. determination of phosphate in soil, (a development by T. Nishimura, Assistant Chemist), be used in all laboratories, *provided* the modified procedure shows consistently a *lower*, though but slightly smaller, concentration of the nutrient than the result obtained on the same soil with the existing method.

## MODIFIED PROCEDURE

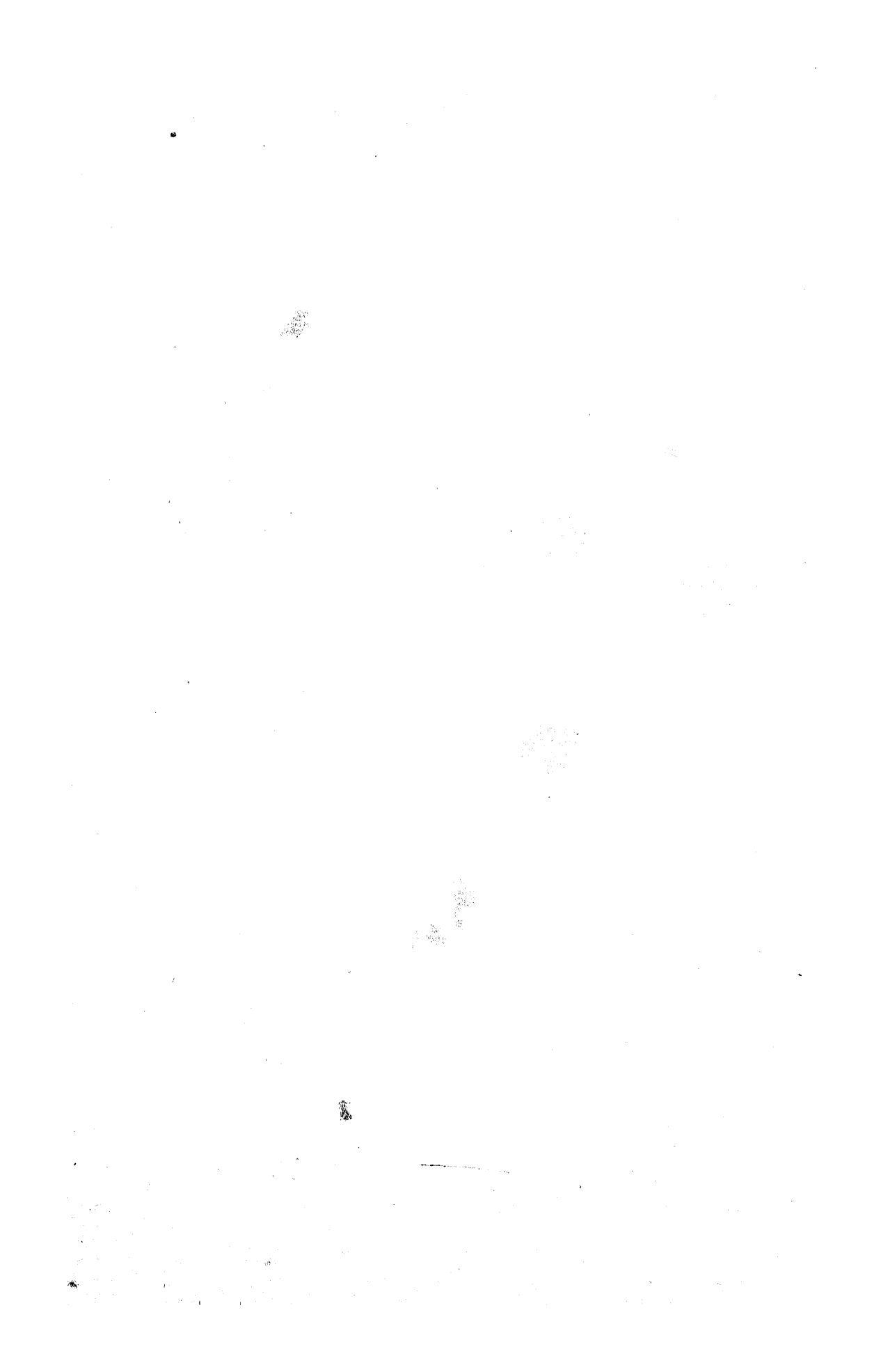
Treat the soil by the regular procedure for the rapid estimation of phosphate in soils up to and including the close of operations in Step No. 10. Then:

1. To the concentrated hydrochloric acid-treated residue, add 20 drops of Reagent 11,  $P_2O_5$  from a dropping bottle.
2. Evaporate to dryness as usual on an electric hot plate.
3. Add 20 drops of concentrated hydrochloric acid and evaporate again.
4. Now, add 10 drops of concentrated nitric acid and evaporate to dryness.
5. Add 10 drops of concentrated hydrochloric acid and again evaporate to dryness. Repeat the addition of concentrated hydrochloric acid and evaporate to dryness once more.
6. Proceed with Step No. 11 of the regular procedure as usual and continue with the rapid estimation of phosphate in soil.

Interfering substances are volatilized or rendered impotent by the modified treatment. Reagent 11,  $P_2O_5$  consists of a mixture of hydrobromic and hydrochloric acids. The appearance of a reddish coloration in the residue after the bromine treatment may be expected. It will be dissipated, however, by the subsequent nitric acid digestion.

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\* A modification of the standard procedure for the rapid determination of phosphate in soil, appearing in *Soil and Plant Material Analyses by Rapid Chemical Methods*, The Hawaiian Planters' Record, 40: 189-299, 1936.



## Occurrence of the Grass Mealybug *Antonina indica* Green on Sugar Cane

By C. E. PEMBERTON

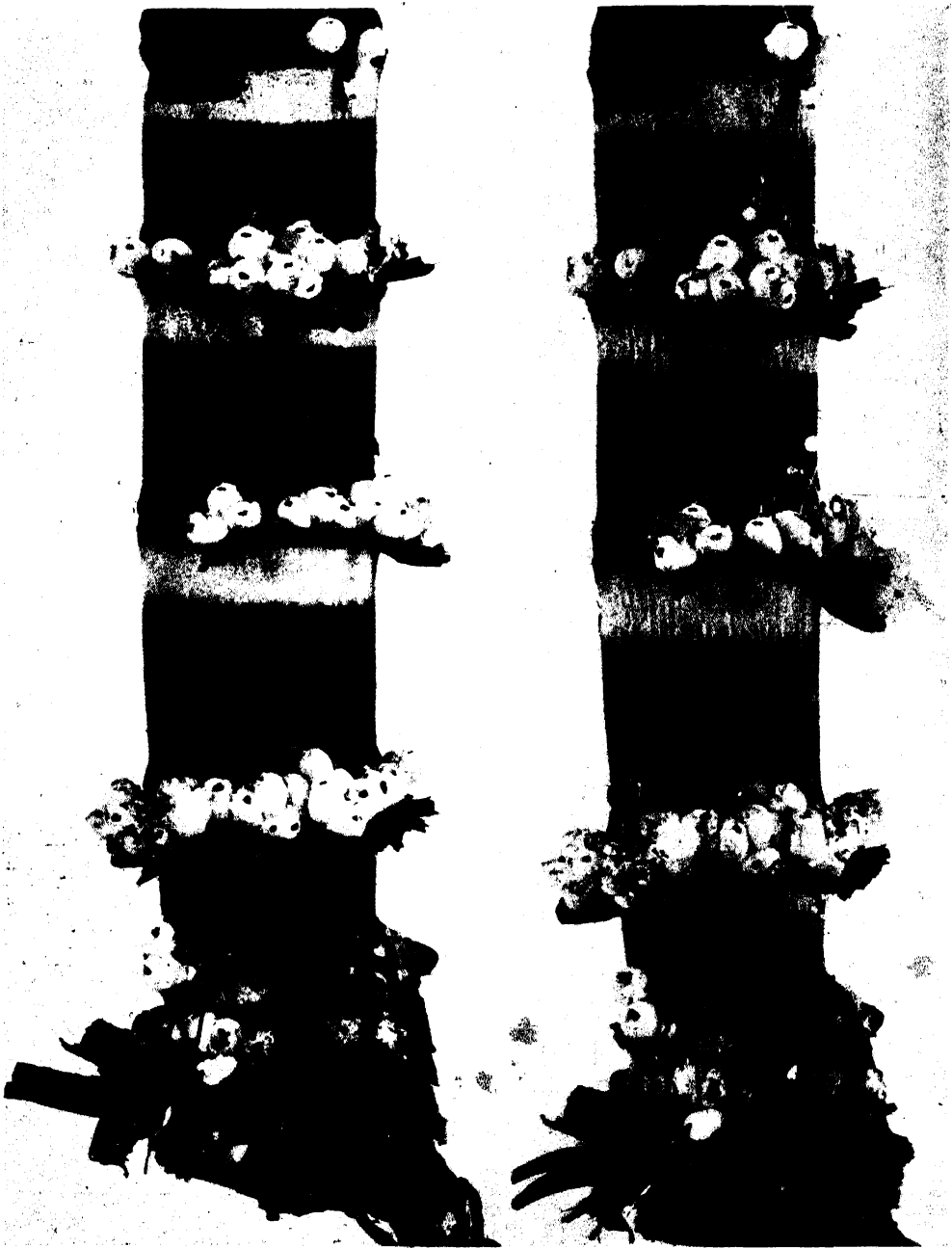
The immigrant mealybug *Antonina indica* Green, which occurs in Hawaii mostly on the nodes of Bermuda Grass *Cynodon dactylon*, has on rare occasions been seen on sugar cane. In September 1931, F. X. Williams reported finding a species of *Antonina* on some sugar cane growing in pots at Mapulehu, Molokai. This was probably *A. indica*. On October 6, 1932, R. H. Van Zwaluwenburg found this mealybug on aerial roots of Lahaina cane growing on isolated tables at the Pathology Plot of the Experiment Station on Alexander Street, Honolulu. O. H. Swezey identified the species as *Antonina indica*.

It is of interest to again record the recurrence of this mealybug in fair quantity on Lahaina cane during the month of January 1938. The mealybugs were found by J. P. Martin massed on the nodes of this cane, which he had growing in sand cultures in pots at the Experiment Station. The pots containing the cane were raised several inches above the ground and were resting on a low wooden platform outdoors. The accompanying photographs, taken by W. Twigg-Smith, clearly show the general appearance of the species as it clusters about the root band on the lower nodes of the Lahaina stalk.

In the photo on the right a short white thread can be seen extending from the posterior end of many of the mealybugs. This thread is a hollow, tubular, wax filament through which the insect exudes a clear, honey-like secretion, technically known as honeydew. This single thread is characteristic of species of *Antonina*. At the tip of some of the threads in the photo can be seen a globule of honeydew. This tubular thread seems to render a useful service in enabling the insect to drop the sticky honeydew away from its immovable body and thus avoid becoming smothered and otherwise hampered by its own viscous, adhesive juices. The wax thread is brittle and when broken off is completely reformed within a few days. The photo on the left shows the mealybugs with the filaments mostly broken off by ants before the cane was cut. The same piece of cane is again pictured on the right a few days later after having been isolated from ants long enough to permit the elaboration of the wax tube.

It is curious that on the few occasions when this mealybug has been seen on sugar cane, the latter was growing in pots off the ground and that the insect seems to favor Lahaina cane.

This mealybug is never likely to be a pest on sugar cane in Hawaii. It was first recorded in the islands by Jacob Kotinsky in the *Proceedings of the Hawaiian Entomological Society* for May 1910. It has undoubtedly been in the islands over thirty years. One or more parasites attack it and are moderately effective.



*Antonina indica* on Lahaina cane.

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## A *Bufo Marinus* of Exceptional Size

By F. A. BIANCHI

Although surprisingly large individuals of *Bufo marinus* are occasionally found in other countries, and the writer himself observed one such in Guatemala, it was not suspected heretofore that any Bufos in the Hawaiian islands had attained the size of the larger specimen shown in the accompanying photographs. By the usual standards of our toad population the smaller specimen pictured is of fair size; being one of a lot that has been kept under observation and regularly fed since 1933, it may be presumed to be, if anything, above the average. By comparison with the larger specimen shown, however, the ordinary toad is a mere dwarf.

The giant is a female. Captured by the writer on Poki Avenue one block south-east of the Kapahulu Fire Station, it was found on the night of February 7, 1938, and is presumed to be an unusually old specimen. In addition to its unprecedented size, the pronounced smoothness and somewhat distinctive coloration of its skin lead to the belief that this toad may be one of the 149 original individuals introduced by C. E. Pemberton from Puerto Rico in 1932. On the other hand, since there is no certain way of judging a toad's age, this giant may be no older than any other of our toads of average size, and in that case its unusual development remains to be explained. Two possible explanations that naturally suggest themselves are a physiological abnormality such as occasionally causes gigantism in other animals, or a very rare combination of circumstances that may have provided this toad with a uniquely favorable environment.

Whereas the common toads of our gardens seldom weigh as much as one pound, the present specimen weighs 2 pounds 9 ounces, has a body length of  $7\frac{3}{8}$  inches, a width of  $6\frac{5}{16}$  inches, and a girth of  $15\frac{1}{2}$  inches around the widest part of the abdomen.



A giant *Bufo marinus* shown in comparison with a normal adult and an average human hand.





A giant *Bufo marinus* with a body length of  $7\frac{1}{2}$  inches, exclusive of the legs.

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## The Plant Food Value of Nitrogen in Filter Cake

By R. J. BORDEN

Continuing our attempt to determine the separate plant food values of sugar mill by-products, the investigation which is discussed hereafter has been concerned with the specific plant food value of the nitrogen content of filter cake.

In previous studies\* of this question, we have been unable to secure any clearly indicated nitrogen response with a crop planted on soil in which filter cake had been incorporated. It has been suggested that these results were perhaps due to the fact that our crops were planted too soon after applying the filter cake, and that a longer period of fallow, between the mixing into the soil of this carbonaceous material (C/N ratio 26:1) and of planting the crop, would result in its more complete decomposition, with subsequent release of its nitrogen content for the growing plants. The present test was therefore planned with this thought in mind.

The soil used was a heavy, clay-like alluvium from the low-lying area (Yamada field) at our Waipio substation. It was neutral in reaction (pH 6.9), deficient in available nitrogen but well supplied with both phosphate and potash. In its natural state, this soil is sticky, tight, and poorly drained, hence the various applications of filter cake temporarily improved its physical condition.

### *The Plan:*

After a thorough mixing, the soil was divided into three principal series and one of these into a subseries, for further specific plant food treatments. (1) In Series I, both the filter cake and the commercial nitrogen fertilizer were added to the soil at the beginning of a six-month period of fallow. (2) In Series II, only the filter cake was added to the soil at the beginning of the six-month fallow period; the nitrogen fertilizer was not added until the end of the fallow at the time the crop was planted. Supplementing four of the treatments in Series II, a subseries was included wherein the six-month fallow periods were modified as follows: to "C"—one month of fallow before adding the filter cake to the soil followed by five months of fallow after it was incorporated; to "B"—two months of fallow without filter cake, followed by four months of fallow after its addition; to "A"—three months of fallow without the cake, followed by three months of fallow after it was added. (3) In Series III, the soil was fallowed without either filter cake or nitrogen for the entire six months, both of these materials being applied only immediately before planting.

Fourteen treatments were included (in duplicate) in Series I, II and III but only Treatments 7, 8, 9, and 10 were used in the subseries A, B, and C. These treatments were as follows:

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\* Some Plant Food Values in Molasses and Filter Cake. The Hawaiian Planters' Record, 39:180-190, 1935.

Treatment No.	Tons filter cake per acre (wet basis— 75% water)	Pounds nitrogen per acre		
		From filter cake	From fertilizer	Total
1	0	0	0	0
2	11	100	0	100
3	0	0	100	100
4	22	200	0	200
5	11	100	100	200
6	0	0	200	200
7	33	300	0	300
8	22	200	100	300
9	11	100	200	300
10	0	0	300	300
11	33	300	100	400
12	22	200	200	400
13	11	100	300	400
14	0	0	400	400

To avoid any possible deficiency, both phosphoric acid and potash were supplied and mixed into the soil of all pots alike, at the beginning of the six-month period of fallow.

During the entire fallow period, the soils (which were all potted) were kept under conditions which should have been favorable for maximum soil-microbial activity. At intervals of two weeks, the soil of each pot was dumped into a clean mixing bowl, thoroughly turned over, and returned to its container. At these times, a soil sample was taken for an analysis (by R.C.M.) of its available nitrogen content.

The pots were all planted with *Panicum* grass in May and thereafter given identical care and treatment. The first crop was harvested in September, 16 weeks after starting. The plants in all pots had been "yellow" and had made no apparent growth for fully four weeks previous to harvest; thus it was believed that they had used up all available nitrogen. After being harvested, the stubble (except for the subseries) was ratooned for a second crop. The absence of any residual nitrogen effects from the original filter cake applications was evident from the very start of this ratoon or second crop.

#### *Discussion of the Results:*

The results can perhaps best be shown on and discussed from the graphs. The dry weights of material harvested are summarized in Table II. The photograph (Fig. 1) shows the plants in Series II at the time of their harvest.

The probable fate of the available nitrogen supply in a fallowed soil which has been supplied with filter cake is clearly indicated in Fig. 2. At the time of potting (November 2) this soil contained 61 pounds of water-soluble nitrogen per acre-foot. In the absence of filter cake, this natural nitrogen supply increased with some regularity up to 137 pounds in January, then for some unknown reason, made a sharp decline in February, but increased somewhat irregularly thereafter, but at no time did it drop back to its starting point.

In contrast to this soil without filter cake, we note that in the four cases following the addition of filter cake, averaging 22 tons per acre and hence containing 200 pounds of nitrogen, the available nitrogen content of the soil which at the time of

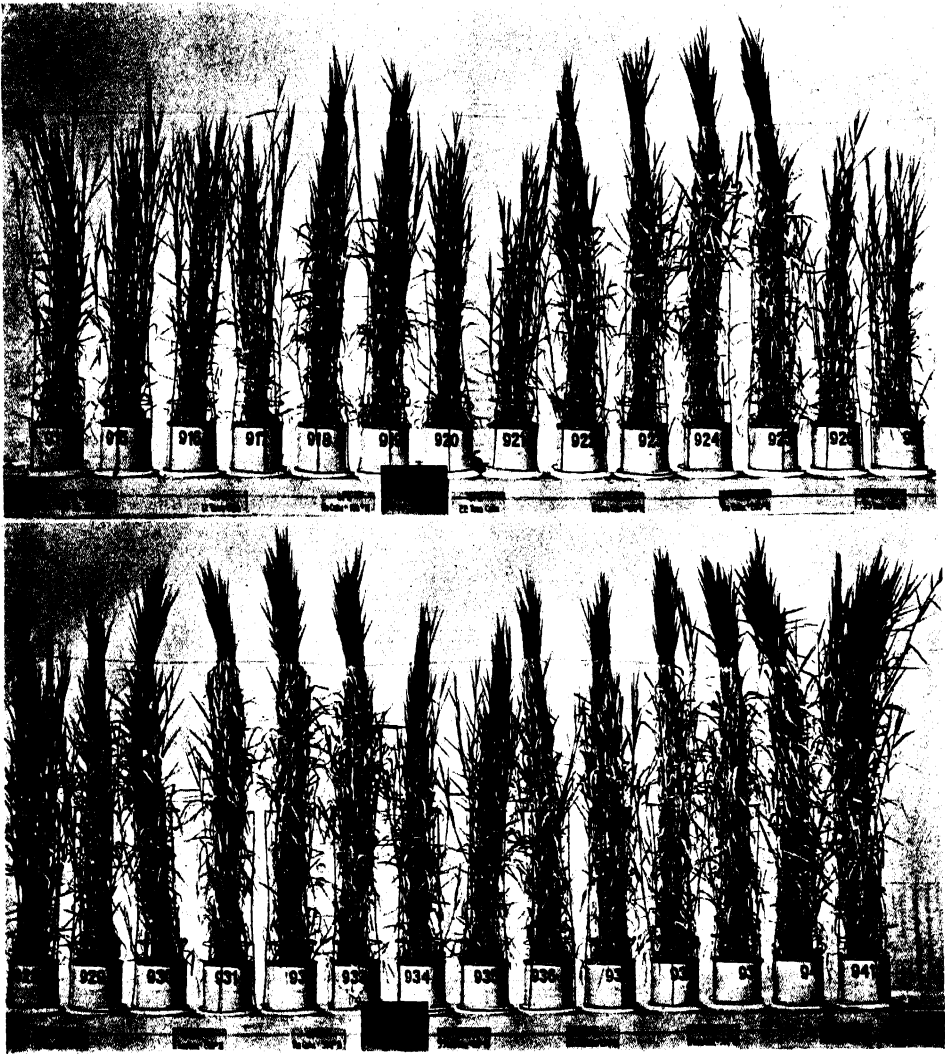


Fig. 1.

Pot Nos.	Treatments
914-915	No filter cake or nitrogen fertilizer.
916-917	100 lb N from 11 tons filter cake only.
918-919	100 lb N from fertilizer only.
920-921	200 lb N from 22 tons filter cake only.
922-923	200 lb N; 100 from cake and 100 from fertilizer.
924-925	200 lb N from fertilizer only.
926-927	300 lb N from 33 tons filter cake only.
928-929	300 lb N; 200 from cake and 100 from fertilizer.
930-931	300 lb N; 100 from cake and 200 from fertilizer.
932-933	300 lb N from fertilizer only.
934-935	400 lb N; 300 from cake and 100 from fertilizer.
936-937	400 lb N; 200 from cake and 200 from fertilizer.
938-939	400 lb N; 100 from cake and 300 from fertilizer.
940-941	400 lb N from fertilizer only.

**Status of Available Nitrogen in Fallow  
Soils (of Series II) Without and  
Following the Incorporation of Filter Cake**

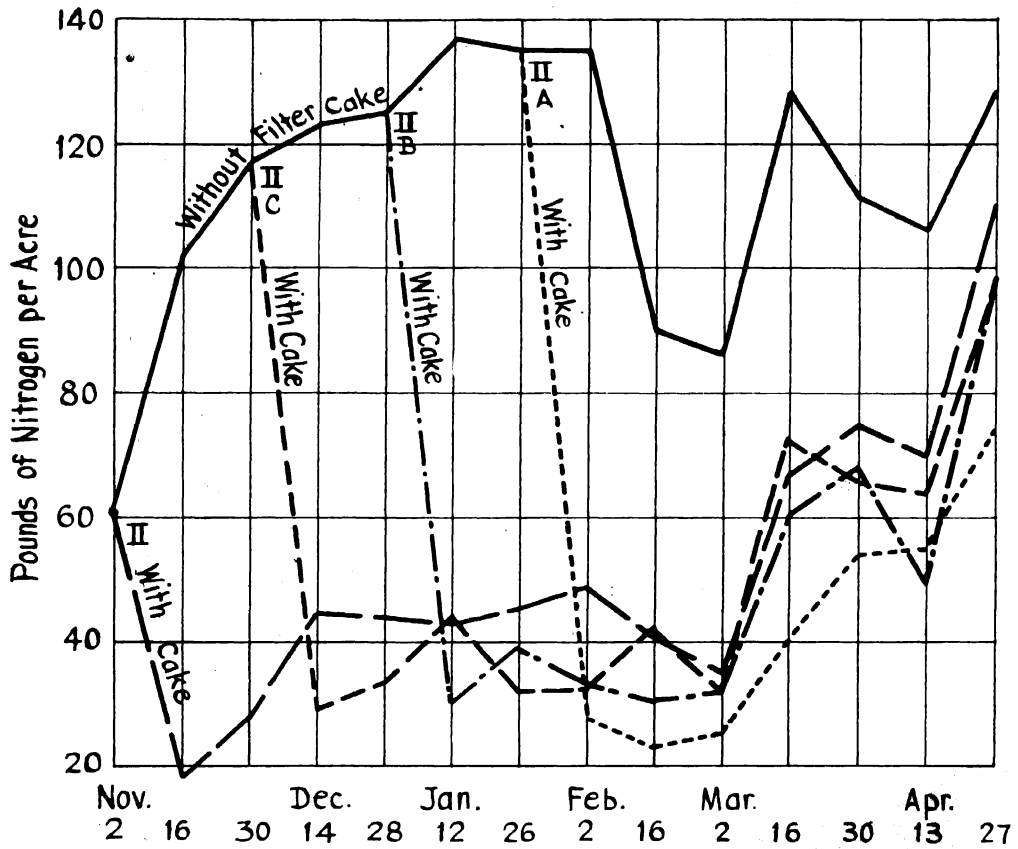
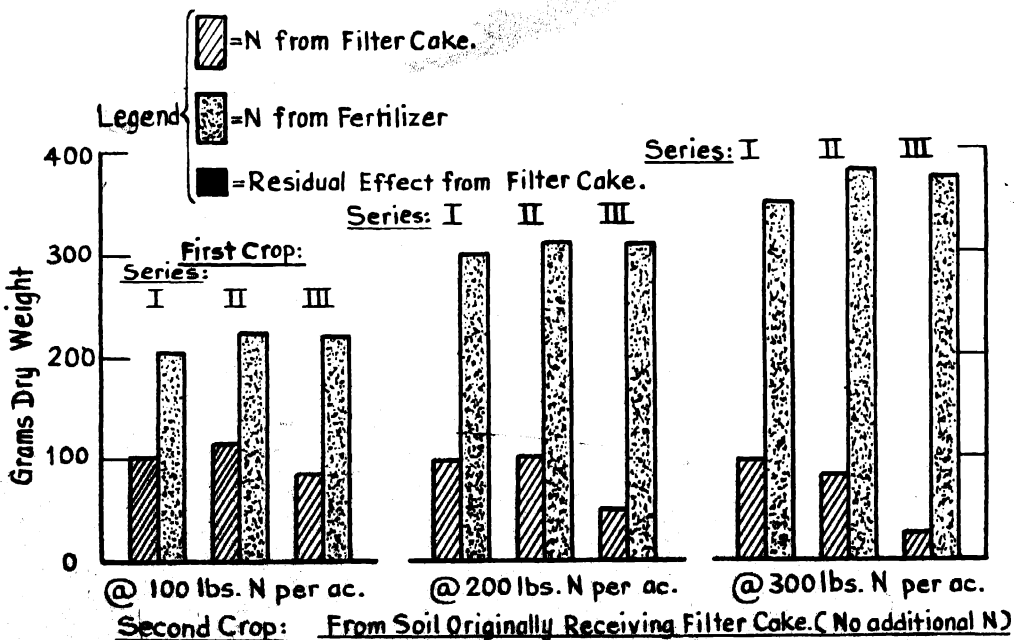


Fig. 2.

**Comparative Yields from Equivalent Amounts of Nitrogen  
Supplied in Filter Cake and in Commercial Fertilizer  
at Various Rates per Acre**



# Dry Weights Secured from Equivalent Amounts of Nitrogen Supplied

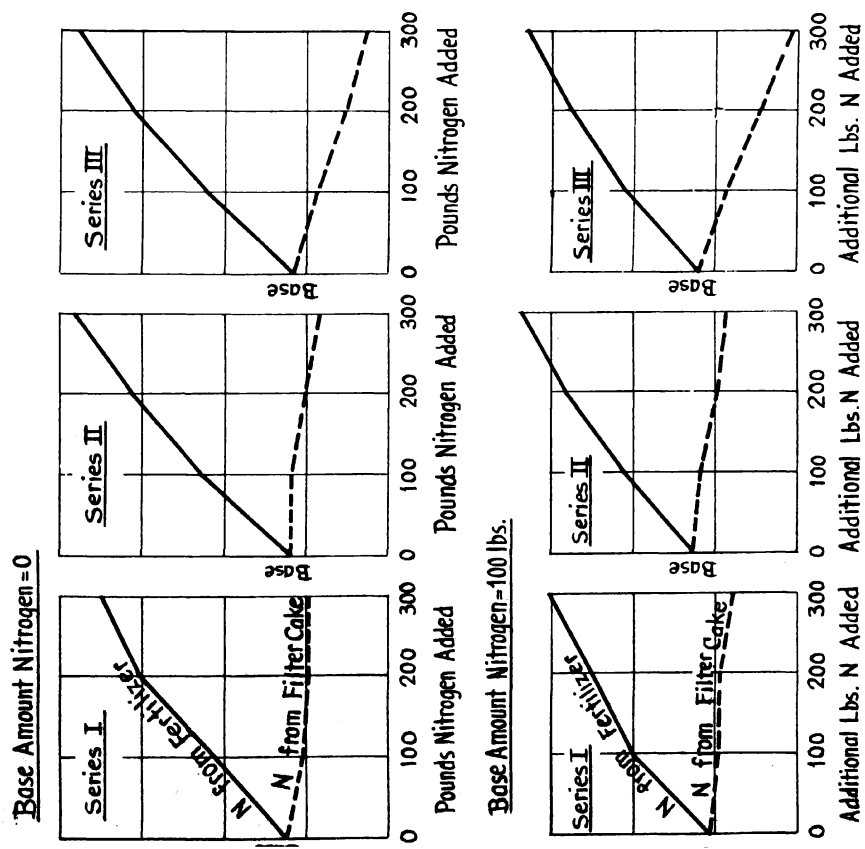


Fig. 4.

# Results Obtained from Equivalent Amounts of Nitrogen from Filter Cake and Fertilizer

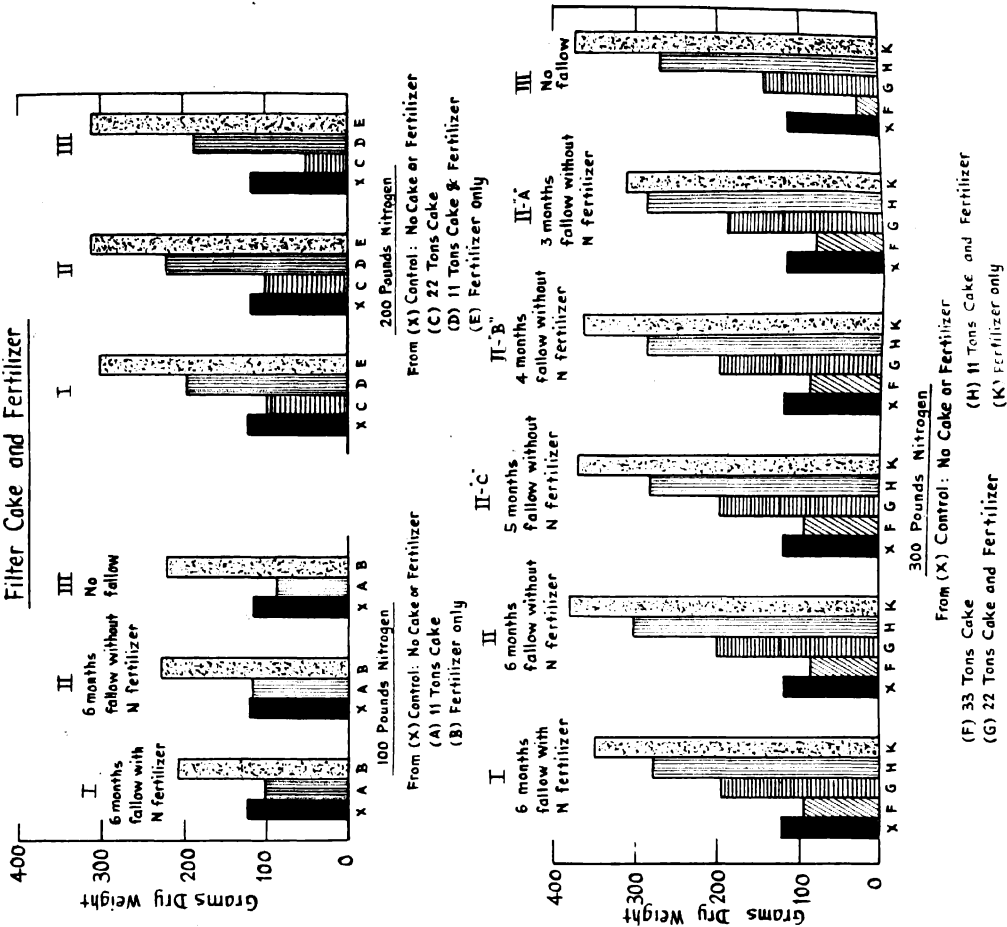


Fig. 5.

incorporation averaged 61, 117, 125 and 135 pounds respectively, was abruptly reduced (within two weeks) to very low levels: 18, 29, 30, and 28 pounds, and remained close to 40 pounds until March. At this time, its nitrogen content also began to increase, and at the end of the six months of fallow, it was on its way to catch up with the nitrogen content of the soil which had not received the filter cake. Thus at the time the crop was planted, the maximum difference between the soils-with-cake and soils-without-cake was only 54 pounds of soluble nitrogen, and there is an indication that such difference was progressively less for those soils which had received their filter cake applications earlier in the fallow period. But it is also true that the nitrogen content of the filter cake, even when it had been in the soil for six months, had not been made available. Furthermore, soil samples taken from each pot after the crop was harvested showed a complete absence of water-soluble nitrogen, and thus verified the foliary diagnosis which had indicated that the supply of available nitrogen had all been used.

It is believed, therefore, that the final answer to our question will be found in the total dry weights produced by soils to which our comparative treatments have been applied. Thus we look at Figs. 3, 4, and 5 with considerable interest.

Fig. 3 very definitely shows that when the nitrogen in filter cake and in commercial fertilizer is compared pound for pound, the filter cake nitrogen is greatly inferior in its availability to a growing crop. Also, whereas increased amounts of nitrogen from fertilizer gave increasingly larger yields, this was not the effect when the same nitrogen increases were supplied from filter cake; in fact, the tendency was for slightly lower yields from the increased amounts of nitrogen supplied in the heavier applications of filter cake. Even a second cropping of this soil failed to show the desired residual effect or to indicate further availability of the nitrogen supplied with the filter cake applications which preceded the first crop.

The first glance at the "curves" in Fig. 4 will also show that the nitrogen added in the filter cake has not been made available to the first crop. Not only this, but it is apparent that the applications of filter cake have actually removed some of the natural soil nitrogen supply to an extent which has resulted in depressed yields. This fact is more apparent in Series III, wherein planting followed immediately after the application of the filter cake to the soil, than in Series I and II which had had the filter cake incorporated for a period of six months before planting.

A similar conclusion must also be drawn from Fig. 5. In every instance, the addition of filter cake resulted in a decreased dry weight for the crop which followed. Mixtures of filter cake with nitrogen fertilizer produced yields which were the equivalents only of the nitrogen fertilizer alone. There is no evidence that the nitrogen in the filter cake was made available for this crop.

The loss due to the addition of 100 pounds of nitrogen from filter cake and the comparative gains which are due to additions of equivalent amounts of nitrogen from commercial fertilizer are given in Table I. These applications of nitrogen from filter cake, to soils which had been built up to basal amounts of 0, 100, 200 and 300 pounds of nitrogen respectively, always resulted in losses in dry weight which were generally significant amounts. Conversely the equivalent nitrogen applications from fertilizer gave consistent and always significant gains. The average gains and losses for the three series indicate that the loss for the filter cake application (11 tons per acre containing 100 pounds N), regardless of the basic amount of nitrogen which

it supplemented, was quite similar. On the other hand, the gains for the nitrogen fertilizer applications (at 100 pounds per acre) diminished somewhat according to the "law of diminishing returns" as the basic amount of nitrogen increased.

These results force us to believe that we cannot expect to secure tangible benefits from, or place any real plant food value on, the nitrogen that is contained in heavy applications of filter cake.

TABLE I  
GAINS OR LOSSES (GRAMS DRY WEIGHT) FROM THE APPLICATION  
OF 100 POUNDS OF NITROGEN FROM FILTER CAKE OR FERTILIZER

Basal amts. in soil (lb N)	Series I— 100 lb N added		Series II— 100 lb N added		Series III— 100 lb N added		Avg. 3 Series— 100 lb N	
	from cake	from fertilizer	from cake	from fertilizer	from cake	from fertilizer	from cake	from fertilizer
0	—19	+ 84	0	+110	—29	+105	—16	+100
100	— 9	+ 94	— 7	+ 86	—35	+ 88	—17	+ 89
200	—13	+ 47	—10	+ 70	—38	+ 65	—20	+ 61
300	— 8*	+ 54	—16	+ 53	—23	+ 53	—16	+ 53

\* Possibly due to chance (less than 2 x SED).



TABLE II  
SUMMARY OF DRY WEIGHTS SECURED FROM 14 TREATMENTS IN SERIES INDICATED

Treatment No.	Tons cake	Original —treatments added— lb N from fertilizer	Series I	Series II	Series II "A"	Series II "B"	Series II "C"	Series III
1	0	0	122.8 $\pm$ .8	117.2 $\pm$ .2				116.6 $\pm$ .9
2	11	0	103.6 $\pm$ 1.4	117.7 $\pm$ .7				87.1 $\pm$ 1.4
3	0	100	206.9 $\pm$ 3.3	227.2 $\pm$ .2				221.6 $\pm$ 3.5
4	22	0	98.6 $\pm$ 2.3	102.9 $\pm$ 6.3				51.7 $\pm$ 1.7
5	11	100	197.7 $\pm$ 1.6	220.8 $\pm$ 1.9				186.8 $\pm$ 1.0
6	0	200	301.4 $\pm$ 2.4	312.9 $\pm$ 1.9				310.0 $\pm$ 1.0
7	33	0	98.2 $\pm$ 4.0	84.3 $\pm$ 4.2	81.1 $\pm$ .2	85.4 $\pm$ 2.0	91.3 $\pm$ .2	27.8 $\pm$ 4.0
8	22	100	195.0 $\pm$ .5	199.3 $\pm$ 2.2	187.7 $\pm$ 2.7	195.4 $\pm$ 2.5	194.6 $\pm$ .5	144.5 $\pm$ 3.8
9	11	200	278.1 $\pm$ 2.7	302.0 $\pm$ .7	284.4 $\pm$ .7	283.9 $\pm$ 1.9	282.3 $\pm$ 3.1	272.3 $\pm$ 1.7
10	0	300	348.7 $\pm$ 3.4	382.0 $\pm$ 1.9	310.8 $\pm$ 1.2	360.4 $\pm$ 2.7	368.4 $\pm$ 4.3	374.6 $\pm$ 3.9
11	33	100	177.3 $\pm$ 1.0	187.7 $\pm$ 1.0				109.8 $\pm$ 2.5
12	22	200	271.9 $\pm$ 1.9	289.2 $\pm$ 1.7				233.0 $\pm$ 2.2
13	11	300	340.1 $\pm$ 3.1	366.3 $\pm$ 2.7				351.2 $\pm$ 1.7
14	0	400	403.2 $\pm$ 3.2	434.6 $\pm$ 5.5				428.4 $\pm$ 3.0
1	0	0	4.1*	8.3*				10.0*
2	11	0	10.3*	8.2*				14.1*
4	22	0	13.5*	9.5*				14.6*
7	33	0	19.0*	11.2*				10.1*

\* Residual effect from second cropping without additional nitrogen, but refertilized with P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O.

## The Analysis of Plant Material for Total Nitrogen, Phosphate and Potash—An Improved and Simplified R.C.M. Procedure\*

By T. NISHIMURA AND FRANCIS E. HANCE

In any type of chemical analysis of plant material the matter of moisture in the specimen must be considered and the method of analysis and interpretation of data should be weighed accordingly.

It is an accepted belief that physiological and chemical reactions in green plant tissue are altered in the process of drying. It is necessary, therefore, to extract and separate various fugitive forms of nitrogen as rapidly as possible under controlled manipulation from the fresh green specimen prior to chemical analysis. Moisture content of a duplicate specimen may be determined separately, and may be used thereafter to refer the nitrogen findings to a dry-weight basis.

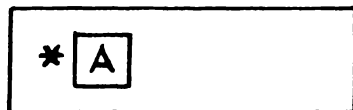
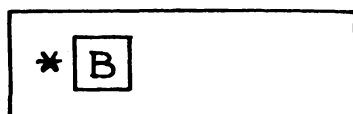
In making a total nitrogen determination in the same material the green weight of the sample from living tissue may vary in moisture percentage from hour to hour while the actual total nitrogen value may remain stationary for several hours. This fact was clearly demonstrated by Paul I. Fagan, Jr. in a study made on Project A 105.117, under the direction of L. R. Smith, where artificial rain was employed to influence the ratio of moisture to dry matter in one set of growing plants. Mr. Fagan's progress report on the study is quoted below:

Object: The effect of rain on the total nitrogen percentage in green-leaf material.

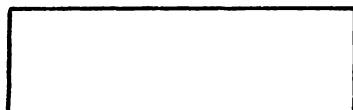
Equipment: Ticket punch for sampling. R.C.M. for total nitrogen, hose for watering cane.

Location and material used: Field 19, Makiki; cane, 31-1389.

MAKAI



MAUKA




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\* A modification of the standard procedures for the rapid determination of total nitrogen, phosphate and potash in cane plant material appearing in *Soil and Plant Material Analyses by Rapid Chemical Methods—II*, The Hawaiian Planters' Record, 41: 135-186, 1937.

Procedure: Sample I, taken January 14, 1938. Selected twelve stalks in both \*A and \*B from which six samples were taken (three from A and three from B). Each sample contained 72 disks, or six from each stalk, or 2 disks from the third, fourth and fifth leaves of each stalk. From 10:30 a. m. to 11:30 a. m. water (artificial rain) was sprayed from above on Plot A.

Sample II, taken at 11:30 a. m. Same as Sample I, except for the different conditions in Plot A. Samples were taken at once to the R.C.M. Laboratory where they were weighed and analyzed.

Detailed results:

Total N in Leaf			
Sample I		Sample II	
A	B	A	B
.52 ± .01	.51 ± .01	.42 ± .02	.51 ± .02

Conclusion: After rain, the total nitrogen in the cane leaf, as shown by R.C.M. analyses, is significantly lower.

It is obvious, therefore, that had the four analyses been made on the individual group of 72 punch specimens each, regardless of their respective weights, the data would have been entirely comparable.

The analytical procedure described below is a modification and simplification of the R.C.M. analyses of plant material. The older method was developed in 1932 at the instance of H. P. Agee, former Director of this Experiment Station. Mr. Agee described the objectives of his proposal for plant material research in a paper entitled *The Sugar Planter Looks at Botany*, submitted at the 52nd Annual Meeting of The Hawaiian Sugar Planters' Association. The revised procedure has been adjusted to allow the research worker full opportunity to employ moisture relationships appropriately with the objective of his study.

The method is applicable to the analysis of any organic material. However, it was developed specifically for the study of fresh sugar cane specimens. The terminology used in the text refers to cane leaf-punch disks.

#### MODIFIED PROCEDURE

The following method enables the operator to make determinations of total nitrogen, phosphate and potash in cane plant material *after a single preliminary treatment*.

##### *Treatment of Sample:*

1. Obtain representative *green* cane leaf material weighing exactly 0.90 gram, (approximately equivalent to 216-225 leaf punches).
2. Transfer material to a 300-cc. Kjeldahl flask.
  - a. Drop two porous granules into the flask.
  - b. Add  $\frac{1}{3}$  spoonful (0.5 gram) of sodium sulfate, C.P. ( $\text{Na}_2\text{SO}_4$ ).
  - c. Introduce 4 cc. Reagent 15, Total-N, with the special pipette.
3. Place on a Type "H" electric heater and digest for 45 minutes.
4. Cool and transfer contents into a 100-cc. volumetric flask. Make up to 100 cc. with Reagent 18, Total N.

*Moisture Determination:*

Investigators desiring to obtain results on a moisture-free basis should proceed as follows:

1. Obtain samples of representative (or composite) *green* cane leaf material in conjunction with the sampling for total nitrogen, phosphate and potash analyses.
2. Weigh the green-leaf material and record the weights.
3. Dry for 3-5 hours in an electric oven at 100° C.
4. Cool dried material in an air-tight container and weigh again.
5. Obtain the percentage moisture, as follows:

Weight of green (fresh) material, minus weight of dried material =  
weight of moisture (H<sub>2</sub>O)

$$\frac{\text{Weight of moisture} \times 100}{\text{Weight of green material}} = \% \text{ moisture}$$

6. Refer the percentage moisture to the "Moisture Correction Table" and obtain its factor.

7. To obtain results on a moisture-free basis, use the formula:

% on green (fresh) material  $\times$  factor = % on moisture-free basis.

MOISTURE CORRECTION TABLE

% Moisture	Factor	% Moisture	Factor
60	2.50	73	3.70
61	2.56	74	3.85
62	2.63	75	4.00
63	2.70	76	4.17
64	2.78	77	4.35
65	2.86	78	4.54
66	2.94	79	4.76
67	3.03	80	5.00
68	3.12	81	5.26
69	3.23	82	5.56
70	3.33	83	5.88
71	3.45	84	6.25
72	3.57	85	6.67

*Total Nitrogen in Cane Leaf Material:*

1. Pipette 25 cc. of solution from Step No. 4, under "Treatment of Sample," into a 300-cc. Kjeldahl flask.

a. Add 75 cc. of Reagent 18, Total N to bring volume to 100 cc.

b. Add 20 cc. of Reagent 17, Total N and immediately place on a heater, together with distillation assembly (as in the determination of Total N in cane juice).

2. Pipette 5 cc. of the distillate into a 50-cc. beaker. Add 25 cc. of Reagent 18, Total N and mix.

3. Pipette 5 cc. of the diluted solution into a comparison vial. Add 1 cc. of Reagent 6, N with the special pipette. Stopper and let stand 1 minute.

4. Compare on the illuminator with the ammonia nitrogen-in-soil color standards. In comparing colors, select an aliquot (5 cc. to 2 cc.) which will produce a color intensity matching almost exactly that of any standard color tube, preferably between Nos. 3 to 6, inclusive.

## 5. Refer to the data sheet for percentages of nitrogen.

## PERCENTAGE TOTAL NITROGEN (WET BASIS) IN GREEN CANE LEAF MATERIAL

(To obtain results on moisture-free basis, refer to Moisture Correction Table)

Aliquots	Standard tube numbers						
cc.	2	3	4	5	6	7	8
5.0	.16	.27	.37	.48	.64	.80	1.07
4.5	.18	.30	.41	.53	.71	.89	1.19
4.0	.20	.34	.46	.60	.80	1.00	1.34
3.5	.23	.39	.53	.69	.91	1.14	1.53
3.0	.27	.45	.62	.80	1.07	1.33	1.78
2.5	.32	.54	.74	.96	1.28	1.60	2.14
2.0	.40	.68	.93	1.20	1.60	2.00	2.68

*Potash in Cane Leaf Material:*

1. Pipette 25 cc. of solution from Step No. 4, under "Treatment of Sample," into a 100-cc. beaker.
2. Place the beaker on an electric hot plate at full heat and evaporate to dryness, or until the evolution of fumes has practically ceased.
3. Cool slightly and add 2 cc. of 1 Normal sodium hydroxide (NaOH). Evaporate slowly to dryness on an electric hot plate at *low heat*. Avoid *spattering*.
4. Add 5 cc. of Reagent 1,  $K_2O$  to the contents of the beaker and shake well. Filter through Munktell No. 3, 7-cm. filter paper.
5. Take aliquots of 1.0, 0.9, 0.8 cc., etc., and make readings, using the technic involved in the usual R.C.M. for potash in soils or in juices.
6. Refer to Table I for the percentages of potash.
7. For samples which are expected to show amounts of potash greater than 0.30 per cent, use 10 cc. of Reagent 1,  $K_2O$  (instead of 5 cc.) in Step No. 4.
8. Then proceed as usual and refer to Table II for the percentages of potash.

## PERCENTAGE POTASH (WET BASIS) IN GREEN CANE LEAF MATERIAL

(To obtain results on moisture-free basis, refer to Moisture Correction Table)

TABLE I

	Aliquots taken (extracted with 5 cc. Reagent 1, K <sub>2</sub> O)										
Readings	1 cc.	.9 cc.	.8 cc.	.7 cc.	.6 cc.	.5 cc.	.45 cc.	.40 cc.	.35 cc.	.30 cc.	.20 cc.
2	.17	.18	.21	.24	.28	.33	.37	.42	.48	.56	.84
3	.19	.21	.24	.27	.32	.38	.42	.47	.54	.63	.95

TABLE II

	Aliquots taken (extracted with 10 cc. Reagent 1, K <sub>2</sub> O)										
Readings	1 cc.	.95 cc.	.90 cc.	.85 cc.	.80 cc.	.75 cc.	.70 cc.	.65 cc.	.60 cc.	.55 cc.	.50 cc.
2	.33	.35	.37	.39	.42	.44	.48	.51	.56	.61	.67
3	.38	.39	.42	.44	.47	.50	.54	.58	.63	.69	.75

*Phosphate in Cane Leaf Material:*

1. Pipette 20 cc. of solution from Step No. 4, under "Treatment of Sample," into a 100-cc. beaker.

2. Add sufficient ammonium hydroxide ( $\text{NH}_4\text{OH}$ ), Reagent 9, N, to neutralize the acid—about 2 cc. (Use litmus paper, if necessary.)

3. Evaporate to dryness on an electric hot plate at low heat. *Avoid spattering.*

4. Add 10 cc. of Reagent 4,  $\text{P}_2\text{O}_5$  and mix well.

5. Using a 5-cc. Mohr pipette, take a 4.0-cc. aliquot from the above solution and make it up to 8 cc. with Reagent 4,  $\text{P}_2\text{O}_5$  in a phosphate vial. (For any subsequent aliquot taken, always bring volume up to 8 cc. with Reagent 4,  $\text{P}_2\text{O}_5$ .)

6. Add stannous chloride solution and compare with cane juice standards, employing the usual R.C.M. technic.

7. In case the intensity of the color developed does not closely match that of the standard tube, repeat Step No. 5, using different aliquots (4.75 cc. to 3 cc.) until an almost exact match is obtained.

8. Refer to the table for the percentage of phosphate.

## PERCENTAGE PHOSPHATE (WET BASIS) IN GREEN CANE LEAF MATERIAL

(To obtain results on moisture-free basis, refer to Moisture Correction Table)

Aliquots cc.	Standard tube numbers							
	1	2	3	4	5	6	7	8
5.00	.035	.053	.071	.089	.107	.124	.142	.160
4.75	.037	.056	.075	.094	.112	.131	.150	.168
4.50	.039	.059	.079	.099	.118	.138	.158	.178
4.25	.042	.063	.084	.105	.125	.146	.167	.188
4.00	.044	.067	.089	.111	.133	.156	.178	.200
3.75	.047	.071	.095	.118	.142	.166	.190	.213
3.50	.051	.076	.102	.127	.152	.178	.203	.229
3.25	.055	.082	.109	.137	.164	.191	.219	.246
3.00	.059	.089	.119	.148	.178	.207	.237	.267



## Some Sugar Yield Relationships

By R. J. BORDEN

The opportunity to determine certain interesting relationships which might be concerned with sugar yields was recently offered when ten years of field records from the Waialua Agricultural Company were made available for study. The results of four questions which were investigated are hereafter presented graphically with short comments and discussion. The study was confined to fields cropped with the cane variety H 109, and all such fields were included.

### *1. Relation Between Sugar Yield and the Crop of a Field Cycle:*

The ability of H 109 cane to produce successful ratoon crops is one of its most valuable characteristics. Under present-day conditions a field cycle of crops, i.e., from one planting to the next successive planting, will seldom include less than the plant crop and four ratoons.

Our first question was, "Under favorable conditions for this cane variety, do the yields of the older ratoons drop off to a point significantly below the yields of the plant crop?" If this question could be answered affirmatively then we should need to give thought to more frequent plowing and planting; if answered negatively, then, unless extra field costs were involved, we might consider an even longer cycle than that now generally adopted.

In order that all sugar yields might be placed on a basis from which fair comparisons could be made, the tons-sugar-per-acre yield (TSA) was divided by the age of the crop (in months) to secure a basic figure of tons-sugar-per-acre-per-month (TSAM).

The field records from 111 fields have quite definitely answered our question—negatively. An inspection of Fig. 1 will clearly show that the TSAM yields from the fourth and fifth ratoons have not been significantly different from those of the plant crops; the crop figures all lie within the range of .448 to .462 tons-sugar-per-acre-per-month, none varying by as much as 2 per cent from the most probable average (.454).

### *2. Relation Between Sugar Yield and Month of Starting the Crop:*

The many disadvantages concerned with starting cane crops too late in the season (after August) or too early (prior to March) have been heretofore accepted as inevitable. Although it is definitely recognized that from an economic agricultural standpoint there is a most opportune time to start cane crops, the physical impossibility of harvesting and milling the annual crop during the short span of best months concerned has forced us to start some crops earlier and some later than is desirable. However, with the acceptance of mechanical harvesting on a 24-hour day schedule, we can foresee a reduction in the overall time needed to take off the cane crop, and providing additional milling facilities are made available, it may no longer be necessary to start many crops in the less favorable, slower growing months.



While it may be true that cane crops started in our mid-season (March-July) will get off to a faster start and close-in before the end of the year, and hence be cheaper to cultivate, is there any relationship between these advantages and the yields of sugar that such crops may produce? The data shown in Fig. 2 would indicate that these advantages are supported by the optimum sugar yields also. Both the best "sugar-per-acre" (TSA) and "sugar-per-acre-per-month" (TSAM) yields from the total of 849 crops studied are found to favor the crops which were started in mid-season; the lower sugar yields are found associated with those crops started before March and after July.

### 3. *Relation Between Sugar Yield and Month of Harvest:*

Quite naturally, since a large percentage of our cane is grown from ratoon fields, there is a direct and close relation between the harvesting of one crop and the starting of another. Therefore it would be unfortunate unless the same relationship with sugar yield were found for both the month of harvest and the month of starting. Fig. 3, however, indicates that this similar relationship did exist, and that the best TSA and TSAM yields were obtained from those crops which were harvested in mid-season, with perhaps a suggestion that February was better than July.

### 4. *Relation Between Sugar Yields and the Age of Crop:*

Since fewer than 8 per cent of the crops concerned were harvested at less than 18 months of age, the so-called short crop is not included in this study. However, Fig. 4 will show that the sugar-per-acre-per-month value for crops between 19 and 25 months was not consistently different, although the best figure was that found for crops harvested at 24 months. This suggested optimum age for H 109 is also supported by the TSA figures which are found to increase quite regularly with increasing age of crop up to 24 months, and thereafter to drop off.

## CONCLUSIONS

Unless field costs are concerned with decisions to plow out old ratoons, there is apparently little to be gained by plowing and replanting H 109 unless it is shown that the sugar-per-acre-per-month yields are falling below the normally expected values.

Under the climatic conditions of the Waialua district, optimum sugar yields from H 109 cane should be obtained from 24 months' cropping, and when the fields are started and harvested between the months of February and July.

## TSAM

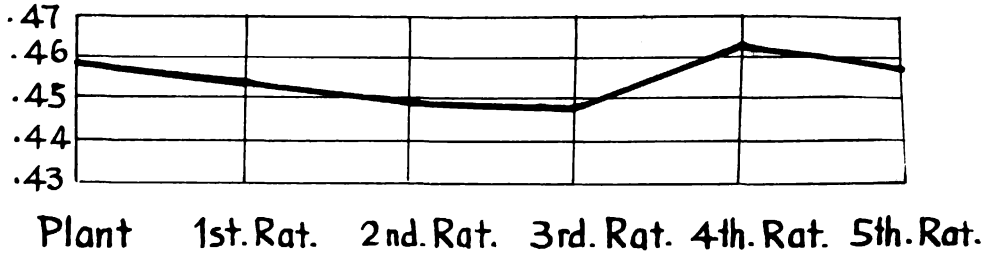


Fig. 1.

## TSA

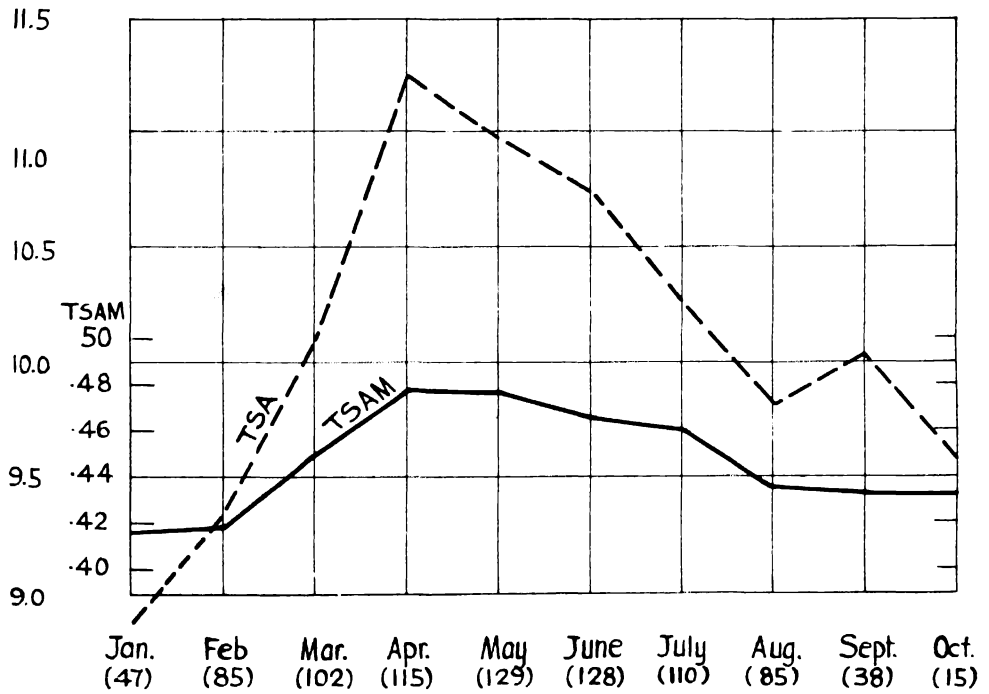


Fig. 2.

TSA  
11.5

11.0

10.5

TSAM

10.0

9.5

9.0

Jan. (52) Feb. (79) Mar. (86) Apr. (102) May (128) June (118) July (118) Aug. (107) Sept. (39) Oct. (20)

Fig. 3.

TSA  
11.5

11.0

10.5

TSAM

10.0

9.5

9.0

8.5

8.0

7.5

7.0

Under 18 Mos. (66) 18 Mos. (31) 19 Mos. (37) 20 Mos. (40) 21 Mos. (74) 22 Mos. (139) 23 Mos. (150) 24 Mos. (168) 25 Mos. (68) 26 Mos. (76)

## Stem Galls of Sugar Cane Induced With an Insect Extract

By J. P. MARTIN

The foremost reference on stem galls is by Kamerling (3) who in 1900 described and illustrated such malgrowths on stalks of sugar cane in Java. In 1907 North (10) observed stem galls on Badila cane at Lautoka, Fiji, and later, on Badila and other varieties in Fiji, Queensland, and New South Wales. Lyon (7) stated that stem galls have been known to occur in Hawaii since 1910 and that they were of little importance prior to 1925 when they appeared in epidemic form on a number of the Uba x D 1135 seedlings. Stem galls of sugar cane have been reported in the following countries: Australia, Cuba, Fiji, Hawaii, Java, Louisiana, and Philippines. No serious losses on commercial sugar cane varieties have resulted from this teratological condition although aggravated cases have developed on certain individual canes in Hawaii, thus making the varieties valueless. These proliferations have been recorded on a large number of varieties in Hawaii which include the majority of the commercial canes; however, on the latter their presence has been of minor importance.

The various types of stem galls appearing in Hawaii have been described and illustrated by Lyon (5, 6, 7) and Martin (8, 9). The first symptom of galls is recognized by the development of watery blisters or slightly raised translucent excrescences on young stalk tissue near the growing point. The galls at this stage of development can be detected only by carefully removing the leaf sheaths from the stalk in the growing-point region. The tissue of stem galls is made up chiefly of embryonic cells which are very irregular in size and shape. The galls soon assume a variety of irregular forms, some of which develop into bud proliferation (Fig. 1) while others develop into large masses of galled tissue (Fig. 2). At times the abnormal growths are confined to the nodal region of the stalk (Fig. 2, lower center) but in most instances the outgrowths or hypertrophies develop on both the nodes and internodes (Figs. 1, 2).

Considerable study by Station Staff members has been devoted to the factor or factors causing stem galls. Plant juices extracted from galls and injected into healthy stalks have yielded negative results. Repeated contact plantings of galled and healthy varieties showed that the healthy plants did not contract the disease. Direct inoculations of diseased tissue into healthy canes failed to produce galls, and isolation studies also failed to associate any organism as being directly responsible for stem galls. Pemberton (11) and Carpenter (2) were of the opinion that the sugar cane stalk mite, *Tarsonemus spinipes*, during its feeding on the stalk, might incite or stimulate certain cells to form stem galls. This particular mite is as a rule present on, and often found close to the growing point of, stalks manifesting galls. A causal relationship between stalk mite infestation and gall formation was indicated by Carpenter (unpublished studies, 1932), who reported that galls on certain cane varieties which always produced galls were prevented by repeated applications of sulphur to the cane tops.

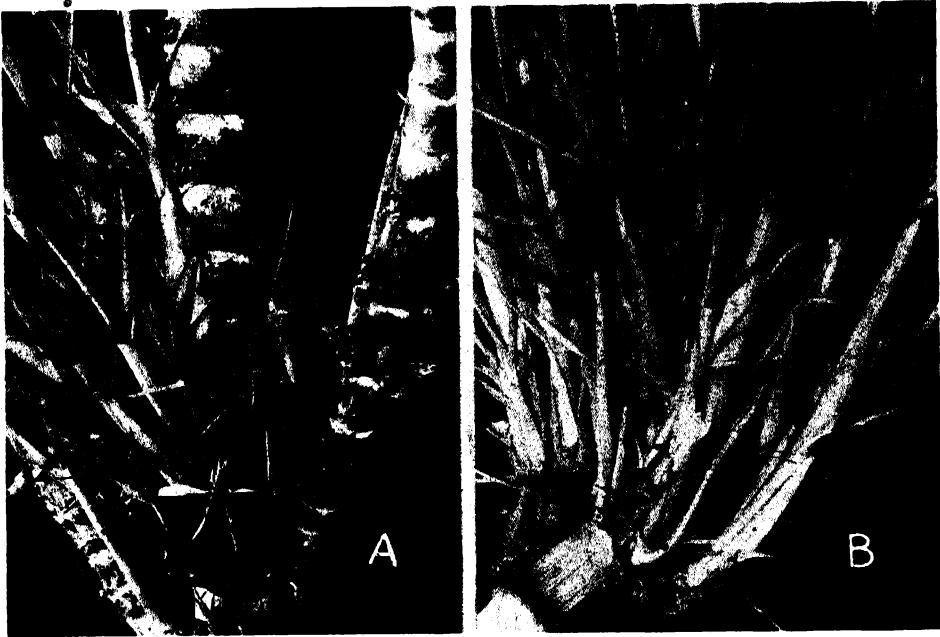


Fig. 1. A, proliferating stem galls on UD 47, many of which have given rise to adventitious buds while some of these have developed into leafy shoots. B, stem galls on UD 47, the majority of which have developed into small shoots. After Lyon (6).



Fig. 2. Stem galls on stalks of UD 1. On the lower portion of the center stalk the galls are confined largely to the nodal tissue. After Lyon (7).

In the Director's Monthly Report of this Station for May 1936, C. E. Pemberton reported the green leafhopper, *Draculacephala mollipes*, of the family Jassidae, to be somewhat common on sugar cane at Kailua substation. Since other insects belonging to this family, such as *Eutettix tenellus*, the vector of curly top disease of sugar beet, and *Cicadulina mbila*, the vector of streak disease of sugar cane, play an important role in the transmission of virus diseases it was felt that the green leafhopper should be studied in relation to certain cane diseases.

In studies connected with the transmission of chlorotic streak disease of sugar cane, a number of green leafhoppers were collected from diseased POJ 2878 plants and allowed to feed on healthy POJ 2878 plants grown in sand cultures and enclosed in screen cages. No transmission of the disease resulted in these experiments.

On May 20, 1936 the writer collected from 40 to 45 green leafhoppers at Kailua substation and macerated them in a mortar with a pestle in the presence of a small amount of distilled water. The extract was then strained through a thin layer of cotton in order to remove any large particles, and additional distilled water was added to make up a volume of 200 cc. By means of a hypodermic needle each of 4 stalks of H 109 and of POJ 2878, growing in aerated and non-aerated nutrient solutions, was inoculated with the insect extract, both above and below the growing point. Seven weeks later (July 9, 1936), 2 stalks of H 109 and 3 stalks of POJ 2878 manifested definite cases of stem galls on internodes which previously had been inoculated, as shown in Fig. 3. The controls in this test remained healthy.

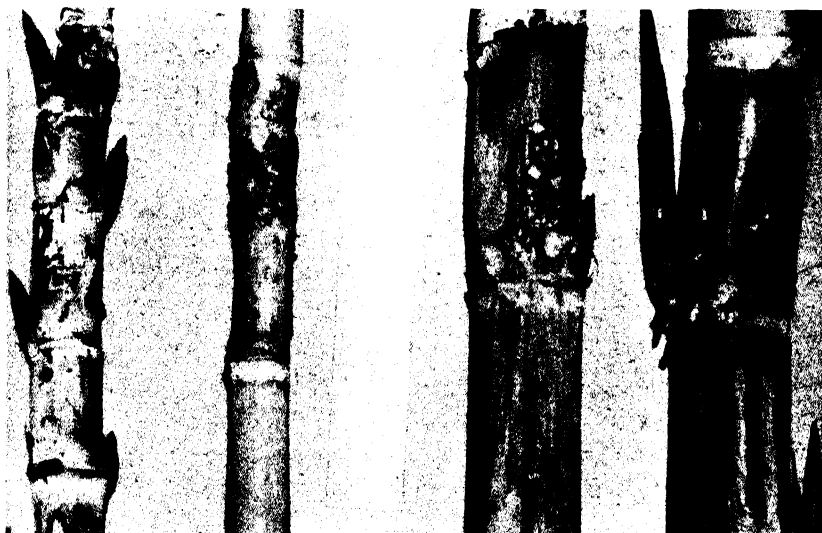


Fig. 3. The development of stem galls on stalks of H 109 (single stalk on extreme left) and POJ 2878. The stalks were inoculated with an insect extract which was prepared from the green leafhopper, *Draculacephala mollipes*. Photograph by Twigg-Smith.

In a second experiment, each of 4 stalks of H 109 and of POJ 2878 was inoculated (July 31, 1936) with an insect extract which was prepared as described above. In this test 35 insects were used in the preparation of the extract. At the end of 14 weeks all inoculated stalks were carefully examined and galls were noted on 2 stalks

of H 109 and 3 stalks of POJ 2878, the first evidence of stem galls having been observed at the end of 8 weeks.

In order to confirm the results of the two previous tests a third experiment was installed October 23, 1937. In this test only stalks of the variety POJ 2878 were inoculated with the insect extract prepared from green leafhoppers which again were collected at Kailua substation. Each stalk was inoculated: (a) slightly below the growing point, as near as could be determined, (b) approximately from 10 to 12 inches below the first inoculation, and (c) about 12 inches below the second point of inoculation, the object being to inoculate stalk tissue of different ages. Six weeks after the inoculations were made stem galls were noted on several of the inoculated stalks. On January 19, 1938, when all stalks were critically examined, 9 stalks out of a total of 21 showed definite cases of stem galls, some of which are shown in Figs. 4 and 5. On several of the stalks the galls were found near the growing point only after the leaf sheaths were removed from the stalk. On 3 stalks, long, thin galls were found at the base of the leaf sheath (Fig. 5) but no galls were observed on the leaf blade. Lyon (7) in 1927 reported and illustrated galls on the leaf sheath of the variety UD 47; in this instance the galls had developed under field conditions. It was interesting to note that the apical bud of two of the inoculated stalks had divided into many buds, thus forming bunch top. One of the five control stalks, which were inoculated with distilled water, showed indefinite symptoms of stem galls: on another stalk bunch top was noted while on two other stalks aborted tassels were observed. It is very likely that a number of the inoculated stalks would have produced tassels or aborted tassels since several untreated stalks of a similar age tasseled during November and December, 1937.

While examining the inoculated stalks on which galls had developed it was evident that the outgrowths had developed only when the inoculation was made slightly below the growing point or in stem tissue which was capable of making further growth. Stem galls did not develop on the more mature portions of the cane stalk.

This is apparently the first instance where stem galls have developed on sugar cane stalks following artificial inoculations. It is possible that the green leafhopper, as well as other insects, may carry certain auxins or growth-promoting substances and when such substances are injected into the plant by insects during their feeding, stem galls may develop.

Brown and Gardner (1) reported in 1936 the formation of galls on the red kidney bean which had been decapitated and smeared with an ether extract prepared from sterilized cultures of *Bacterium tumefaciens*, the organism which causes crown gall. They also report gall formation on bean, tobacco, sunflower, and other plants following an application of lanolin mixtures containing indoleacetic and indolepropionic acids to decapitated stems. According to Went and Thimann (12): "The root nodules of leguminous plants are active auxin-forming centers when still growing, and their initiation and growth are almost certainly due to the auxin produced by the invading bacteria. . . . These can therefore be considered as root-galls, arising by pathological swelling of a lateral root initial." LaRue (4) in 1936 showed that leaf outgrowths or intumescences on leaves of *Populus gradidentata* developed when healthy leaves were injected with extracts prepared from gall-bearing leaves;



Fig. 4. Stem galls induced on stalks of POJ 2878. The stalks were inoculated October 23, 1937, near the growing point, with an insect extract prepared from the green leafhopper. Galls were first noted December 2, 1937. Photograph by Twigg-Smith.



Fig. 5. Stem galls on a stalk of POJ 2878 that developed following artificial inoculation with an insect extract; long, thin galls also developed at the base of the leaf sheath. Photograph by Twigg-Smith.



he also reported the development of intumescences on leaves injected with indole-acetic acid and " . . . assumed that plant hormones are the cause of intumescences on leaves confined in unventilated damp chambers." Went and Thimann (12) state: "Probably many other pathological outgrowths are explicable in terms of auxin—a development which will open important fields in plant pathology." These are only a few of the interesting results being secured with growth-promoting substances and are presented merely to show that galls may be induced on plants when injected with various auxins.

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## The Giant African Snail *Achatina fulica* (Fér.) Discovered in Hawaii

By C. E. PEMBERTON

An omnivorous and highly destructive plant pest entered Hawaii from Japan through the mails in November 1936. Its presence here and the date of arrival have just been determined. It has been identified by Dr. C. Montague Cooke, Jr., Malacologist of the Bernice P. Bishop Museum, as the notorious African snail *Achatina fulica* (Fér.). Considered indigenous to East Africa, this pest has spread eastwards during the past 75 years and caused great destruction to vegetable crops and other plants in Ceylon, India, and Malaya. In recent years it has reached Borneo, Java, and Amoy, China. It is also said to occur not only in East Africa, but also in West and South Africa and the Seychelles (10). It was introduced into Mauritius from East Africa nearly 100 years ago. Although it could be easily conveyed amongst plants transported from one country to another, its spread during historic times seems to have been mostly intentional, both for use as food for ducks, poultry, and humans and possibly for its assumed medicinal value. The circumstances attending the discovery of this pest in Hawaii are as follows:

According to information supplied by L. M. Whitney, Chief Plant Inspector, Territory of Hawaii, a Honolulu resident read in a local newspaper that a Japanese of Makawao, Maui, was raising these snails for food or medicinal purposes. He obtained six living snails from the grower at Makawao and sought information from the Board of Agriculture and Forestry in Honolulu respecting suitable methods for their propagation. This was early in April 1938. The serious nature of the situation was recognized and especially after Dr. Cooke had positively identified the species. The six snails were confiscated and destroyed and Mr. Whitney immediately proceeded to Maui to discover their source. With the assistance of the sheriff and the county attorney of Maui the snail grower was located at Makawao and his establishment inspected. It was found that the snails were being multiplied by the hundreds in covered, wooden boxes, partially filled with moist sand, kept indoors within the grower's house. Lettuce, carrots, and cabbage were being used as food and the snail colony was in a thriving condition. The entire lot was immediately destroyed with boiling water and buried underground. A total of 1,387 snails from two months to one and one-half years of age was counted. The hatchery also contained a large quantity of newly hatched snails and eggs, which were also destroyed. The grower stated that he had already eaten 425 snails. He assured Mr. Whitney that the only snails which had left his hatchery were the six individuals which had been confiscated in Honolulu. Mr. Whitney found no evidence of snails outside the hatchery and it is hoped that none has escaped or been distributed excepting the six that reached Honolulu.

Further investigation by Mr. Whitney revealed that the Makawao resident had imported 12 of these snails through the mails from Japan on November 25, 1936, without informing the Plant Inspectors of the introduction. There was evidently

no conscious evasion of the law intended. Of the 12 imported individuals, 8 arrived alive on the above date and reached Makawao on November 30, 1936.

This mollusc feeds on many kinds of plants, as well as animal and vegetable refuse. Dammerman (4) states that in Java:

This snail is a serious pest of vegetables and flowering plants; it eats nearly everything in the garden, *Crinum* and other lilies seeming to be preferred for attack, but it is not found on any perennial plant, rice, etc. The snails sometimes occur in such enormous numbers that they are used as poultry-food, especially for ducks, and they were probably originally imported into Singapore for this purpose. They are also eaten by the Malays.

Leefmans (8), in discussing the recent occurrence of the snail in East Java, writes that:

Damage was only conspicuous on banana leaves, which were rather generally and strongly eaten, which damage looked alarming enough to take measures. Furthermore some damage to orchids and ornamental plants and to the bark of shrubs were observed. Some vegetable gardens were only yet slightly invaded. . . . In the large center at the village Sockaboemi [elevation 2,300 feet] a campaign was organized to have the snails collected by the natives. More than 2 millions were caught, thrown in especially dug small pits, crushed with poles and covered with earth.

This snail has been in Ceylon long enough to have become a pest of real importance. According to Hutson (5) it reached Ceylon about 1900. It had already been recorded in Calcutta since about 1857 and had been introduced there from Mauritius (1) by an enthusiastic malacologist, who used it for purposes of dissection. In describing the damage caused by the snail in Ceylon, Bertrand (2) states that:

This pest (*Achatina fulica*), . . . has spread over the whole of the wet zone low-country and is spreading in many Upcountry districts.

It causes immense damage to vegetable and flower gardens and of late years has become a serious menace to certain estate green manures and cover crops. Two years ago this estate [Govina Estate, Horana] was covered with a beautiful carpet of *Vigna* which has since been almost completely destroyed. During the whole of 1927 all children who came to muster were sent off for an hour or two to collect snails and a total of at least 9,000 working hours was so employed. Towards the end of the year it was realized that the snails had got completely beyond control and the work was stopped.

It was represented to the Agricultural Department that the only effective check which we have against soil erosion in grown Rubber was in danger of extinction and the Department was requested to make enquiries in Madagascar as to what agency there controls the snail. So far the only "control" reported is a big bull-frog which eats them, but the Director of Agriculture is not in favor of such an importation. [Note: The above reference to Madagascar is probably a typographical error. The reference is no doubt to the island of Mauritius.—C. E. P.]

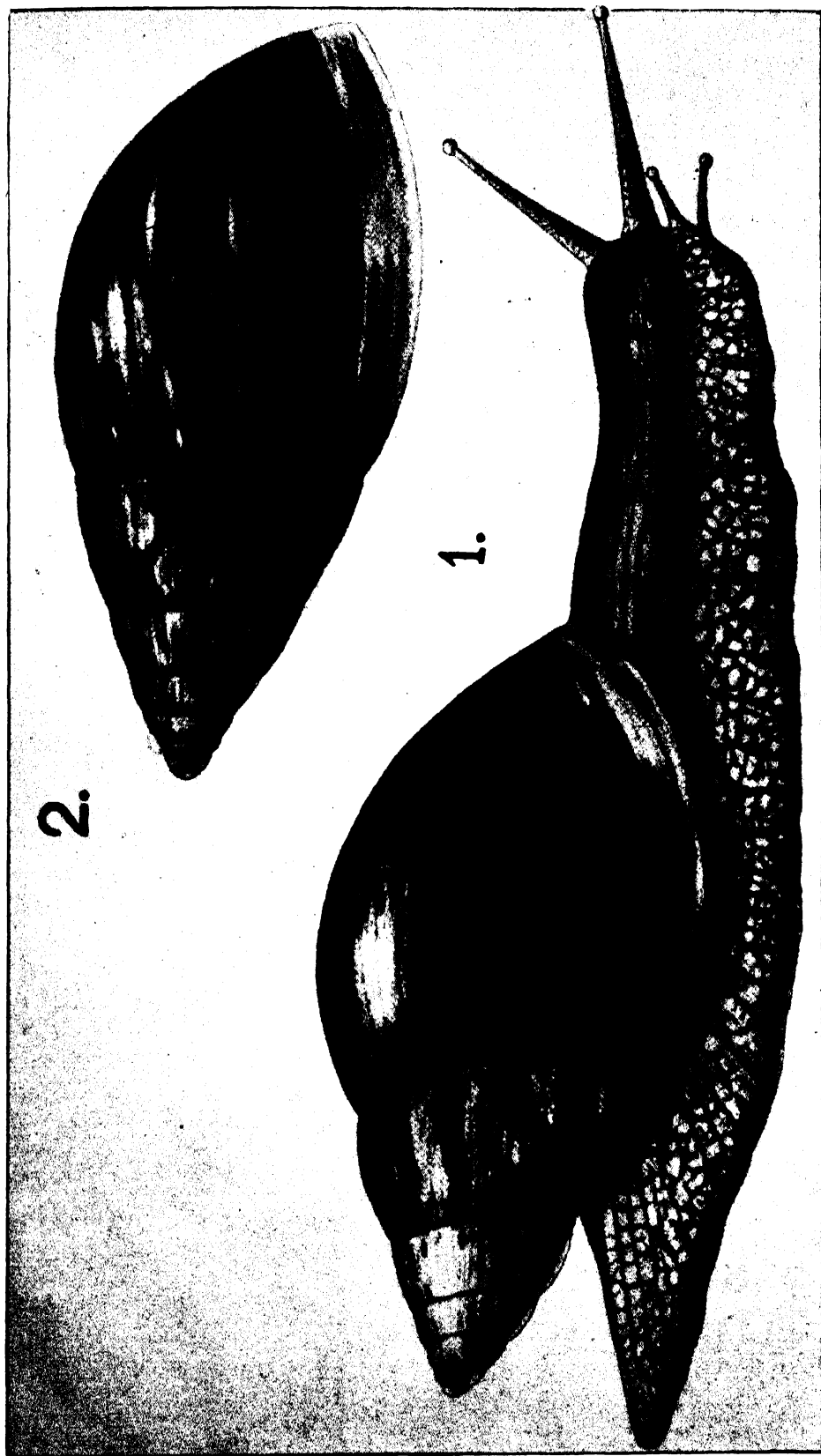
South (10), commenting in 1926 on the presence of the snail in Malaya, states that:

The exact date when the presence of these snails in Malaya first received attention is uncertain, but the available evidence indicates that they have been present in Kedah and Singapore for about 15 years.

Jarrett (7), in remarking on its status in Singapore says:

A few notes on the way the creature has spread in Singapore may also be of interest. First taken serious notice of in March, 1922, when it occurred in a small area in the heart of the island, it rapidly spread. In 1928, the writer passed through Singapore while going on leave, and learned that the snail had become a thorough pest in gardens all over the island. One house in the Tanglin residential district was visited, and there the molluscs were shaken out of a hedge like ripe apples off a tree!

Latest information [1932] from Malaya is that the snails are now found in increasing numbers everywhere, and even wander over the golf courses, where the chagrin of a player whose ball is stopped by a giant mollusc in the grass may be imagined.



Giant African Snail *Achatina fulica* (Fér.). Natural size.

1. The crawling snail with its shell. 2. The shell showing variations in color pattern.

(From Leeftmans and Van der Vecht, Landbouwkundig Tijdschrift Voor Nederlandsch-Indië, Vol. 8, page 670, 1932-33.)

The snail is a comparatively recent arrival in Borneo. Referring to its history there Jarrett (6) states:

Introduced there from Singapore, apparently as feed for poultry carried across as live stock, in 1928, the snail was identified at Kuching the following year, and by 1930 was already a pest. This year, serious efforts have been made to keep its numbers down, and a small reward was offered to the natives for its destruction. Between October 1 and October 15, 1931, approximately half a million snails and twenty million eggs were destroyed! The increase of the mollusc in only three years seems almost phenomenal, and serves as a warning to us in China. The reference to eggs in October seems to establish, what was long suspected, that in the equatorial region, where there are no marked seasons, these snails probably lay as soon as mature, possibly throughout the year.

South (10) has given a good description of the life history and development of the snail. He says:

*Achatina fulica* has a shell which in average local specimens [Singapore] is between 4 and 5 inches long, though occasionally examples may be found as much as 6½ inches long. The greatest width is between 1½ and 2 inches.

The snails probably take two years to attain their full size, but are capable of laying eggs at the end of the first year when half grown. So far as is known at present, the eggs are laid only once a year. . . . In Ceylon and India the half grown snail lays about 100 eggs in a pocket and the full grown snail from 200 to 300. Each individual is bi-sexual, as is usual in the snail family, but pairing may be necessary to produce fertile eggs.

The eggs are about the size of a large pea. They are round and yellow, with a hard shell like that of a bird's egg. Batches of eggs are laid in shallow pockets just below the surface of loose soil in sheltered places. Thus they can be found in soil at the foot of trees, under hedges, below rank vegetation, under large stones, broken bricks and crockery or old ironware, or in heaps of vegetable refuse or manure.

Hutson (5) states that under favorable conditions eggs may hatch within two or three weeks after being deposited. The young snails are about the same size as the eggs and emerge with their own body shells fully formed. They feed voraciously at an early age and are quite inconspicuous for the first month at least. The Giant Snails feed mostly at night and in the early morning. During the heat of the day they rest, usually in sheltered places, as for example under hedges, under thick vegetation, under trees and in rubbish heaps. Where they are numerous, they are also to be found resting on the trunks of trees, the stems and branches of hedge plants, the sides of drains, or the walls of houses.

Hutson (5) further says:

These snails are active only during wet weather and retire during dry spells to sheltered places, closing up the mouth of their shells by means of a parchment-like cover, the hibernaculum, which they secrete as required.

During the wet weather the snails do most of their feeding at night, especially in the younger stages, and many of them retire in the early mornings to selected retreats, coming out again at night. When very numerous a large number do remain above ground all day in a quiescent state, clustering thickly on trees, hedges, fence-posts and buildings, and advantage can be taken on this habit to treat with copper sulphate the places where they congregate, or simply to collect and destroy them.

Jarrett (6), in discussing the outcome should the snail be introduced into Hong Kong, China from Amoy, where it has been found, says:

It need hardly be mentioned in conclusion that this snail is a very destructive visitor to gardens or vegetable plots, as its tastes are omnivorous. Lily plants, all succulent herbs, cabbages and lettuces, and anything that is not too hard or distasteful, will be devoured. A few specimens of this mollusc in a Peak kitchen garden patch would probably, in a single night, consume the product of the whole season's devoted toil.

Artificial control of this pest has been attempted with some measure of success over small areas in several countries. Hutson (5), Jarrett (6), South (10), Corbett (3) and others have discussed the use of copper sulphate ( $\text{CuSO}_4$ ) solutions as a poison. Hutson says:

A 4 per cent. solution (2 lb  $\text{CuSO}_4$  dissolved in about 5 gallons of water) will kill all snails if these are immersed in it for about 5 minutes.

He states further that when used out-of-doors copper sulphate in crystal form is effective when placing:

... a small piece of copper sulphate near each young plant. The snails on coming to feed on the plants tend to crawl around them first and come into contact with the copper sulphate crystal sticking out of the ground. These crystals last indefinitely.

Any fine powder or dust, such as sifted wood ashes, sawdust, or coconut husk dust, can be steeped in the 10 per cent. solution of copper sulphate for several hours, and then used as a barrier for vegetable beds, plants, or trees, either in shallow ditches, or sprinkled over a wall of stones.

Hutson found rope, so treated, also an effective barrier for individual plants or flower beds of small size.

One important natural enemy of the snail has been found in India. This is a large glow-worm *Lamprophorus tenebrosus* Wlk. The larva feeds specifically on snails and preys extensively on the Giant Snail and is otherwise harmless both as a larva and adult. Paiva (9) has given an excellent account of its interesting habits.

Corbett (3) refers to inquiries made respecting natural enemies of the snail in East Africa, where it is considered native and states that none has been discovered; but that the snail is not regarded as a pest in that region. He mentions the possibility of dry climate being responsible for its comparative rarity and also suggests the probable effect of predatory birds and snakes. Reference has already been made to the reported usefulness of the "Bull-frog" of Madagascar which feeds on the snail. (Note: This is, as stated before, probably a mistaken locality and Mauritius is meant and the "Bull-frog" is probably a large toad common in Mauritius.—C. E. P.) Ducks and poultry have also been mentioned as feeding on this snail. Hutson (5) says:

Recent information from a correspondent indicates that wild pigs devour snails in the jungle, while recent letters in the daily press state that the "Jungle Crow" or "Etikukula" (*Centropus chlororhynchus*) is very fond of the snails in some localities.

Hutson mentions also that no internal parasites are as yet known to attack the snail. It is probable that *Bufo marinus* would feed on the young snails, should the pest ever become established in regions where the toad occurs.

We find no records of this snail feeding upon sugar cane or pineapples. In India definite observations have established the belief that the snail will not feed on growing rice. In view of this it can hardly be expected to attack sugar cane.

The accompanying excellent illustration, taken from Leefmans and Van der Vecht, Landbouwkundig Tijdschrift Voor Nederlandsch-Indie, Vol. 8, page 670, 1932-33, shows in perfect detail the appearance of the snail and the shell which it occupies, in natural size.

*Note:* Since the above was written six more lots of this snail have been discovered in Honolulu, totaling nearly 800 snails and many eggs. These are reported by the growers to be the progeny of two snails brought into Honolulu alive by a woman returning from a visit to Formosa in 1936. They were carried in a suitcase

and not detected by inspectors, nor were they declared. Another lot was also discovered on Māui recently. These belonged to a resident in a pineapple plantation camp. All of these new lots of snails have been destroyed.

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## Defining Colloidal Solutions\*

By HUGO P. KORTSCHAK

Before one tries to talk about anything, one should know what one is talking about. However, in trying to define the term "colloidal solution" one immediately runs into difficulties and contradictions. The most usual definition depends on the order of magnitude of the size of the particles dealt with. When the cross section of at least one of the dimensions of the particles lies between  $10^{-7}$  and  $10^{-5}$  cm., you have a colloidal dispersion.

Now, that would be a very nice definition, except for several objections. One is, of course, that there is no sudden change in properties as these limits of size are reached. There is no great difference between such particles and those which are just outside these boundaries. Also, there are many substances which, especially when the diameter is near the upper limit, can hardly be considered colloidal at all.

Another definition would say that colloids will pass through filter paper, but not through semi-permeable membranes. That would leave the decision up to the fineness of the filter paper and the kind of membrane. In fact, all measurements which require that a substance pass through any sort of filter are very difficult to evaluate. Just to illustrate: a suspension of gold which will be held back by a filter paper will pass through it easily when a small amount of gum is added, which increases the size of the particles. We usually think of a filter as a kind of sieve, but this is true only for very coarse material. As the material is more finely subdivided, absorption plays a very great role, as do electrical effects.

A definition which would narrow the field far more than is commonly accepted depends on the settling or not settling of the material. This would, in fact, eliminate almost all of the simple cases where complications such as hydration are lacking. Certainly there would seem to be a fundamental difference between, for instance, a suspension of chalk in water which will settle in a few hours, leaving a clear liquid above, and a solution of dye which may be kept for years with no evidence of sedimentation. The former type is often called a suspension; the latter, a truly colloidal solution. What, however, is sedimentation? It does not mean, as is so often assumed, that all the disperse matter separates from the medium. On the contrary, an equilibrium distribution is reached, which may be calculated from the barometric formula, in the same way that the barometric pressure for various heights above the earth's surface is calculated. If you have a pile of rocks under water, you can calculate how many will be floating ten feet above the bottom. Unfortunately, no one has ever made a large enough pile of rocks, or watched it long enough, to verify the prediction experimentally. Perrin, with particles of gamboge  $3.7 \times 10^{-3}$  cm. in radius, verified the value of  $N$ , the gas constant, by showing that the concentration decreased 50 per cent in the height of one-tenth of a millimeter, which compares with 5,000

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\*Presented at a meeting of the Hawaiian Section of the American Chemical Society, March 24, 1938.



meters for a 50 per cent decrease in the pressure of the atmosphere. With the naked eye, one would think Perrin's suspension had settled completely.

On the other hand, we have colloidal solutions which do not appear to settle at all. This led to the belief that the barometric formula failed for such dispersions. However, Svedberg pointed out the simple fact that even the slightest non-uniformity in temperature, caused, for instance, by somewhat one-sided illumination, would set up convection currents strong enough to mask the settling. In recent years, with the development of the ultra-centrifuge, it has been shown that even such a very stable solution as one of sodium chloride settles out exactly as the formula requires for particles of the size and density involved. So this definition—that colloids do not settle—must be abandoned because we are unable to find anything which conforms to the definition.

The truth of the matter is that we have tried, as usual, to force nature into a straitjacket of our own contriving and find it impossible. We are left to the conclusion that no exact definition is possible. We have a general idea as to what we mean, and in every particular case we must make an appropriate definition for ourselves. How important this can be is shown in the sugar industry. In many investigations sucrose solution is considered to be colloidal, but when a sugar boiler wants less colloids in the syrup he certainly does not include sucrose under that heading.

We probably get a better idea of what colloids are when we consider the various forces which may be active in holding the particles in solution.

The simplest case is where the substance is inert and the only effective force is the friction against the medium. Even here we can only predict the behavior of the suspension when the particles are spherical and when the radius, densities and the viscosity of the medium are known. For such a case, Stokes' law for the velocity of falling particles, with the barometric formula, will give us a fairly exact picture of what will happen when such a suspension is allowed to stand. I repeat, that is the simplest case. We can make suspensions of this kind but would be hard put to find a single example in nature, especially among the biological colloids, which are the most interesting and important.

As soon as the particles reach a size of less than  $10^{-4}$  cm., the effect of the Brownian movement becomes noticeable. Some of you may have read about colloid chemistry and become confused by what are called "critical radii," which make it appear to the unwary that the Brownian movement can prevent settling. This is not the case. In our simplest kind of suspension we can calculate the *average* displacement, parallel to any given axis, which will be caused by the Brownian movement for any specified length of time. When this distance is greater than the fall of the particles during this time, the effects of sedimentation will be masked. However, as the Brownian movement is completely random (being caused primarily or secondarily by the kinetic motion of the molecules of the medium) this average displacement must approach zero as the length of time is increased. Thus, the average settling velocity will not be affected at all.

What *will* be affected is the equilibrium which is reached, for without the Brownian movement there would be none. The Brownian movement is evidence of the fact that the particles have kinetic energy. In the usual barometric formula we find a temperature term, but temperature is only a measure of kinetic energy. Thus,

the greater the Brownian movement, the less the particles will have settled at equilibrium.

Up to now I have been discussing the colloids as if the colloidal particles had no effect on each other, were indeed, like the classical atom, perfectly elastic spheres. The forces of attraction and repulsion are very important. When the forces of attraction become effective, the particles become attached to each other, on contact, forming larger and larger aggregates which settle out rapidly. This is called coagulation. A preponderance of repulsive forces obviously prevents this taking place.

Picture to yourself a pile of coil springs, one on top of the other. If the springs are strong and the pile not too high, it will seem as if even the bottom spring is not compressed at all. As we build the pile higher though, the springs at the bottom will become more and more compressed. Thus, in a colloidal solution, when the repulsive forces are strong, it may appear that sedimentation has been completely negated. This is only due to the grossness of our observations, however. A concentration gradient is always present and can be clearly shown by substituting the force of the ultra-centrifuge for gravity, or by using sufficiently high vertical tubes.

In most cases these repulsive forces are of an electrical nature. They may be produced by several effects. When the colloidal material has the nature of an acid, base or salt, true ionization takes place. The soaps are a good example. Let us examine the more common case—that of an acidic substance. When the hydrogen-ion concentration of the solution is small, the substance will be largely dissociated into hydrogen ions and a colloidal, negatively charged residue. These negative particles repel each other and cannot coalesce. If the hydrogen-ion concentration is increased, the ionization is repressed to an extent dependent on the dissociation constant of the acid. There will be more neutral particles present and when these collide, their cohesive attraction may hold them together. Thus, as the pH of the solution becomes lower, the velocity of coagulation becomes greatly increased. The case of a basic colloid or a salt, which hydrolyzes, is of course similar.

An important fact to keep in mind is that in such a case, where true electrolytic dissociation is the cause of the electric change, there is no definite hydrogen-ion concentration at which coagulation takes place, for there are always some undissociated molecules (or neutral aggregates of molecules) present. Thus there is always a finite velocity of coagulation.

Another source of electric charges may be absorption. If a dilute solution of potassium iodide is treated with dilute silver nitrate, the sol is not stable if exactly equivalent amounts are used. If there is a small excess of silver nitrate, the sol is stable and positive; if there is a small excess of potassium iodide, the sol is stable and negative. This is interpreted to mean that in the presence of silver nitrate, the silver ions are absorbed by the silver iodide particles while the nitrate ions are not, thus resulting in a positively charged sol. In the presence of potassium iodide the reverse is true; iodide ions are absorbed, potassium ions are not, resulting in a negative sol. Suppose we have a stable sol of this kind and add any substance which dissociates electrolytically. The resulting ions will be absorbed in differing degrees by the sol. If the sol is positive and the added positive ions are more strongly absorbed than the added negative ions, nothing will happen; the sol is even more stable than before. However, if the added negative ion is preferentially absorbed,

it will tend to neutralize the charge on the particles. As more and more of the salt is added, a point is reached at which the absorbed negative ions have completely neutralized the positive charge on the colloid. The protective electric charge being thus removed, coagulation can take place. Actually, of course, exact neutrality is not necessary. There is a finite cohesive force between the particles and all that is required for coagulation is that the repulsive force be smaller than this. Thus there is a narrow zone of small charges, corresponding to a concentration range of the added electrolyte, in which coagulation takes place. For, suppose we add more of the salt than is required to neutralize the positive charge on the sol. If it is added rapidly enough, enough negative ions will be absorbed to give the sol a negative charge before it has had time to coagulate. This is called "reversal of charge." The addition of electrolytes may also cause coagulation if an insoluble or non-dissociated compound is formed with the absorbed ion.

A source of electric charges which is most common in aerosols, that is smokes or fogs, is ordinary static electricity, caused by friction. Such charges may reach a very high potential; dust explosions and lightning may be caused in this way.

One very important factor which keeps colloids in solution is hydration. Whether colloidal particles carry a water (or other solvent) sheath is largely dependent on the chemical nature of the substance of which they are composed. So-called hydrophobic sols, suspensoids, such as those of metals, carry little or no absorbed water; while hydrophilic colloids, or emulsoids, appear to be associated with large hydration. Such a water layer around the colloid particles keeps them from approaching each other and thus prevents the formation of larger aggregates. Any change which will remove this water layer will cause flocculation.

As to the amount of water which is bound in this way, opinions differ. From Einstein's viscosity equation, the volume of the hydrated particles may be calculated. The ratio of this volume to that of the unhydrated particles ranges from 0.9 for egg albumin, and 1.6 for sucrose, to 220 for agar in water, 300-500 for rubber in benzene and 200-900 for polyvinyl acetate in benzene. And now, please forget these figures. They are probably worth exceedingly little. For the factor of 2.5 which goes into the Einstein equation is true only for spheres. It is probably many times 2.5 for long, rod-shaped particles. Since the factor for non-spherical forms has not been worked out, and particle-shape cannot be determined with any accuracy anyway, there is at present no possibility of quantitative evaluation of such measurements. Other measurements of hydration are no better, and the various methods do not give concordant results.

It is difficult to know how the water of hydration is situated with respect to the rest of the colloid particle. In some cases, no doubt, it actually assumes the form of a nearly spherical shell. In others, it is thought that the particle itself is porous and the water fills the pores as it would a sponge.

Hydration is not, of course, limited to matter in a colloidal form. Most ions are assumed to be hydrated. The so-called hydrogen ion, for instance, being probably a monohydrate,  $H_3O^+$ , to a great extent, with unhydrated ions present only in a very small concentration in any aqueous solution. So we have here another link between colloids and true solutions.

All the properties that have been mentioned in this discussion are in one way or another connected with the surface of the particles. The fact that sedimentation takes place, instead of a practically instantaneous falling of the particles, is due to friction; Brownian movement is evident only when the moving surface is large enough to be apparent to us; absorption and, in many cases though not always, hydration are determined by properties of the surface. These properties are most evident when particles are so small that the surface area is relatively large, but when they are large enough so that it is possible to conceive the surface as being relatively homogeneous.

Thus colloid chemistry is the study of systems where the reactions of surfaces are important, and it is also known by the perhaps better name of surface chemistry.

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## The Introduction Into Hawaii From Mexico of Insect Parasites to Control Armyworms (1923-1924)

By HERBERT T. OSBORN\*

At the request of D. T. Fullaway, Territorial Entomologist, the writer was granted leave of absence from the Hawaiian Sugar Planters' Experiment Station in August 1921, and commissioned by the Territorial Board of Agriculture and Forestry to conduct entomological investigations in the southwestern part of United States and in Mexico. First consideration was to be given to insects which might be of benefit in the hornfly problem, and attention was to be given to mealybug enemies and armyworm enemies as opportunities presented.

In the spring of 1923 the search for armyworm parasites in Mexico was taken up more definitely by an arrangement supported by both the Hawaiian Territorial Board of Agriculture and the Experiment Station of the Hawaiian Sugar Planters' Association. Fred Muir and O. H. Swezey advised me particularly to endeavor to obtain the *Euplectrus* and *Apanteles* which Albert Koebele had sent from the State of Morelos in Mexico in 1902 and which had failed to become established. It was also desired to secure colonies of *Calosoma* beetles which had been sent by Mr. Koebele at various times but failed to become established. Some search had been made in the vicinity of Cuernavaca and Cuautla, Morelos, and in Atencingo and Rabosa in the State of Puebla in the fall of 1922, and in the early spring of 1923; however, the desired insects were not encountered and the conditions for collecting were quite undesirable. Early in March 1923, the fall armyworm (*Laphygma frugiperda*) was injuriously abundant on corn about Cordoba, Vera Cruz, and occasionally appeared in young cane (damage by *Laphygma frugiperda* was frequently noted in widely separated sections of Mexico), but it was considered more desirable to work in infestations of *Cirphis* if such could be found.

After a short stay at Cordoba return was made early in March to the Hacienda El Potrero, Vera Cruz, where work proceeded on armyworms and continued for several months. The Hacienda El Potrero is an American-owned sugar plantation of some 15,000 acres largely planted to sugar cane, but with extensive pasture and woodland. Through the courtesy of A. H. McLane, the general manager, I was privileged to live at the plantation central. This proved to be an ideal arrangement for the projects in which I was then engaged. I had been told that occasional outbreaks of caterpillars occurred in cane in that vicinity, and in my previous visits I had occasionally noticed some slight evidence of armyworm attack.

In searching over the plantation it was found that small infestations occurred, although seldom more than a few acres in extent, and that there was a very scattered occurrence of the caterpillars in wider areas. The species present were of the genus *Cirphis* and most of the individuals which I reared were *Cirphis latiuscula*. The

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caterpillars of this species hide away in the daytime and can be found by stripping down the cane leaves. Usually they were in well-grown cane, and could be located by their characteristic feeding effects on the cane leaves.

#### DISCOVERY OF *Euplectrus platyhypenae* AND ITS INTRODUCTION INTO HAWAII

Almost at once it was evident that the two parasites *Apanteles* and *Euplectrus* were present. The *Euplectrus* being external in its feeding habits was more readily detected and collected for shipment and, in those early infestations, it appeared to be the more effective, breeding up quickly on the small caterpillars and suppressing the incipient outbreaks, at least temporarily, so completely that it interfered with the collecting of other species of parasites.

The method of attack and development of *Euplectrus* on the armyworms also made it particularly easy to ship them after collection, and it was thought best to make trial shipments at once without waiting to study the life cycle, although it was evident that this would be completed very quickly. The parasite eggs were laid in clusters on the body of the armyworm, externally, and the larvae, when hatched several days later, also fed in clusters on the outside of the body. From 20 to 40 or more parasites would develop on one host. The larvae develop to their full size in a very few days, and when full-grown migrate to the underside of the dead caterpillar body and spin a threadlike mass which fastens the body of the caterpillar to a cane leaf or other object, the parasites pupating within this matrix.

Shipments were made of all stages of the parasite from egg to pupa, but it was later found that because of the short life cycle, only those sent in the earlier stages had a chance of arriving in Honolulu alive. With the very best connections it took at least three weeks from the time of collection in the field at El Potrero to the arrival of the shipment in Honolulu. Material for the first shipment was collected near El Potrero from March 13 to 16, and, as it happened, the best recovery of *Euplectrus* in Honolulu was secured from this shipment. Mr. Swezey who handled the shipment on arrival in Honolulu secured 454 living adults of *Euplectrus platyhypenae* Howard from the lot.\*

Several additional shipments of *Euplectrus* were made in the succeeding weeks although the infestations of *Cirphis* were being held to insignificant numbers. No attempt was made to breed parasite material for shipping, the parasitized caterpillars used being those collected from the field. Any caterpillars found not attacked by *Euplectrus* were held in the hope of rearing out other species of parasites.

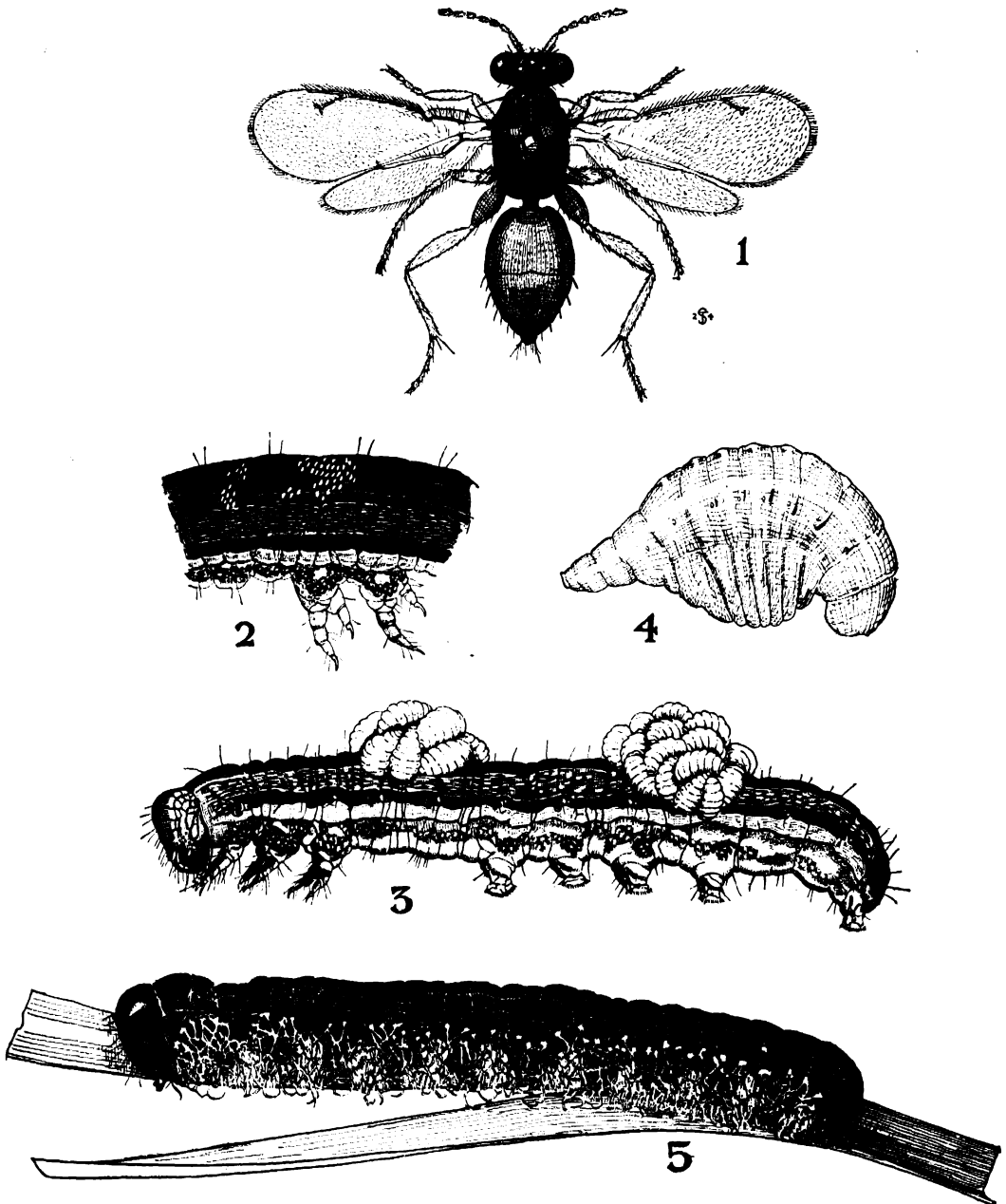
In May, small caterpillars of the commonest armyworm began reappearing on young ratoon cane, and plans were made for shipping some of these on the chance of catching the internal parasites (*Apanteles* and others) before the hyperparasites got them.

Soon after this a letter was received from Mr. Fullaway telling of *Euplectrus* being reared in Honolulu at both the Board of Agriculture and at the Experiment Station, H.S.P.A. On learning this, shipments of *Euplectrus* were discontinued and attention was turned to other species of armyworm parasites. (Within a year

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\*The details of this shipment are given by Mr. Swezey in The Hawaiian Planters' Review, 33: 318-320, 1924.

45,000 of the parasites were reared and distributed to all the sugar plantations and other places where it was learned that armyworms were present. It was found to have become established late in 1924 on the island of Hawaii and later on the other Islands.)



*Euplectrus Platyhypenae*

A Mexican armyworm parasite which has been introduced and widely distributed in an effort to control armyworms.

1. Adult female, x 15.
2. Part of an armyworm showing clusters of white eggs, x 4.
3. Armyworm with two clusters of full grown parasite larvae, x 3.
4. Full grown parasite larva, highly enlarged.
5. Dead armyworm fastened to leaf by the cocoons of the parasites, x 3.



*Apanteles militaris* (WALSH)

Considering that some of the other parasites might prove just as valuable in Hawaii as the *Euplectrus*, I had hopes of securing some of them before leaving El Potrero or perhaps find them also at Puebla. It is hard to value the different parasites where the issue is confused by the presence of hyperparasites and other factors. Once a small lot of pupae of *Euplectrus* brought in from the field and retained in the laboratory yielded mostly hyperparasites.

Another parasite very common in the spring of 1923 at El Potrero, Vera Cruz, in the incipient infestations of *Cirphis latiuscula* was a species of *Apanteles*. The white cottony masses of cocoons on the dead caterpillars made by this parasite were very conspicuous in the cane fields, but the earlier larval stages were not so easy to find since larvae feed and develop internally in the caterpillars. For this reason it was more difficult to collect this parasite in stages early enough for shipping to Hawaii. After the cocoon stage was reached it was too late to ship without emergence of the adults before arrival. Caterpillars shipped from infested lots either failed to contain parasites, or if they did, the parasites emerged and died enroute. Also in the vicinity of El Potrero the cocoons collected in the field were found to yield a very high percentage of hyperparasites.

In December 1923, while on the west coast of Mexico at Los Mochis, Sinaloa, several thousand cocoons of an *Apanteles* were secured and sent to Hawaii. At this season it was much cooler and I was also shipping much more direct, so that a very considerable number of the *Apanteles* emerged in Honolulu and were liberated in the fields. Attempts were made to breed this particular parasite continuously at Los Mochis, but no definite results were obtained. This *Apanteles* was identified as *Apanteles militaris* (Walsh). It failed to become established in Hawaii. It is possible that this species is more specialized in its host relationship than is *Euplectrus*.

## SMALL TACHINID

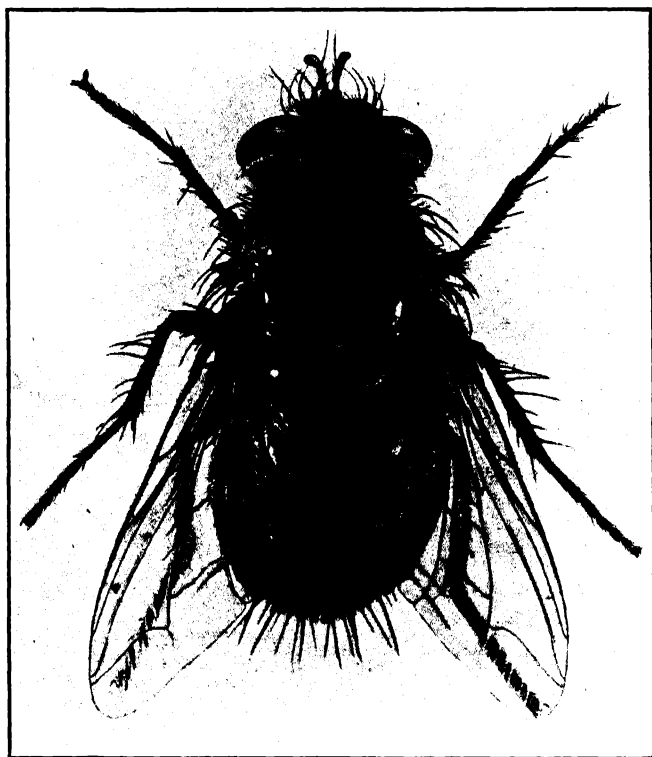
At El Potrero, Vera Cruz, in July and August 1923, after the rainy season was well advanced, an outbreak of armyworms of greater intensity developed over an area of several hundred acres, and it appeared for a while as if it would become even more widespread. As the generation of caterpillars reached maturity, however, they suddenly became so heavily parasitized by a small tachinid fly that very few reached the adult stage. I had previously reared out a few of this tachinid, which is distinguished by the fact that it completes its development in the larval stages of the *Cirphis*. It also differs from some of the other tachinids in Mexico in that several may develop in a single host. Occasionally up to five or six may be obtained, although many caterpillars have only one, and the average probably not over three or four.

From the rapidity with which it overtook a threatened outbreak of the *Cirphis* it seemed to me as possibly the most promising of the parasites observed on the armyworm in Mexico. Large numbers of the tachinid puparia were collected and two shipments made to Honolulu, but because of the extremely short life cycle all of the flies emerged before arriving in Honolulu and were dead when the consignments

were received. No identification was obtained for this tachinid. [With air service it should be possible at some time to introduce this tachinid into Hawaii successfully.—O. H. S.]

A LARGE TACHINID, *Archytas cirphis* CURRAN

At El Potrero, Vera Cruz, in the spring of 1923, and in fact wherever I collected armyworms in Mexico, tachinids would be found to be present. One type was very large, developing in the armyworm caterpillars but usually pupating in the chrysalis of the armyworm. Several consignments containing this type of tachinid were made from Vera Cruz but the caterpillars were so scarce at the time the collecting was done that only a few were sent. Quite a few of the flies issued in Honolulu, however, and an attempt was made to rear them in a cage, which resulted in failure.



*Archytas cirphis*

In December 1923, while at Los Mochis on the west coast of Mexico, I collected a few of what I took to be this same species and sent a few puparia to Honolulu in January 1924. They arrived in good condition and a few flies issued and were released directly into the field where armyworms were present. Despite the very small number released—nine—the fly became established in about one year's time and eventually spread to all of the Hawaiian Islands.\*

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\* The release, recovery, distribution, etc., in Hawaii, and an account of the larviposition habit of this fly are given by Mr. Swezey in Proceedings of the Hawaiian Entomological Society, 6: 490-503, 1927. Its description by Curran is on page 497 of the same publication.

## RESULTS FROM THE INTRODUCTION OF PARASITES OF THE ARMYWORMS

It is much more difficult to make a definite statement as to the results of the introduction of the two parasites—*Euplectrus platyhyphenae* and *Archytas cirphis*—into Hawaii than it was in the case of the introduction of *Pseudaphycus utilis*, the parasite which has given 100 per cent control of the avocado mealybug. There have always been wide fluctuations in the abundance of armyworms in Hawaii. Also, two species of very efficient parasites on armyworms, *Hyposoter exiguae* (Viereck) and *Telenomus nawai* Ashmead, have appeared naturally in the islands within recent years. It will perhaps be several years before it is safe to consider that a balance has been established and, in case it develops that the armyworms are not completely controlled, it may be considered advisable to make additional introductions. A great many parasites quite likely as effective as those already introduced are known to occur in various localities and no doubt many more could be found if intensively searched for in different localities. One shipment of about 150 beetles of *Calosoma semilaeve* Le Conte was made from Cuernavaca in 1923. They arrived in good condition and attempts were made to rear them but apparently they did not become established, nor have efforts to establish carabid beetles from California been successful.

R. A. Vickery made a study of *Cirphis latiuscula* in the gulf coast region of Texas (*Journal of Agricultural Research*, 32: 1099-1119, 1926). *Apanteles militaris* is considered by him as the important parasite in Texas, and *Euplectrus platyhyphenae* is recorded as reared from a small percentage of caterpillars. Obviously, it would have been easier to collect and ship parasites from Texas than from Mexico. At the time I took up that work, however, I was already working on other projects in Mexico. As it has turned out, while I might have collected the *Euplectrus* in Texas, the tachinid *Archytas cirphis* is not listed from Texas by Vickery, nor does the smaller tachinid which I found in Vera Cruz appear to be in the Texas list.

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## Introduction Into the Hawaiian Islands of Mexican Enemies of the Avocado Mealybug

By HERBERT T. OSBORN\*

While on entomological investigations in Mexico for the Board of Agriculture and Forestry of Hawaii, the writer was instructed among other things to give attention to the study of enemies of mealybugs, particularly for the avocado mealybug, *Pseudococcus nipae* (Maskell), and the pineapple mealybug, *Pseudococcus brevipes* (Cockerell).

The avocado mealybug had been a serious pest on avocado, fig, guava, mulberry, some of the palms, and other trees and shrubs in Hawaii for a considerable time. Albert Koebele had made several introductions of enemies for this mealybug but none had proved efficient.

Although some search was made while I was on the west coast of Mexico in the States of Sonora, Sinaloa, and Nayarit in the fall and winter months of 1921, it was not until the spring of 1922 that, at D. T. Fullaway's suggestion, I transferred to the east coast of Mexico and began work more particularly on the mealybugs. Arriving in Vera Cruz early in March, a short time was spent in locating a favorable region in which to work on *Pseudococcus nipae*. Under the conditions existing at the time it seemed that Orizaba was a more favorable locality to work in than Jalapa, where Silvestri had reported the efficient ladybeetle *Hyperaspis silvestrii* Weise to be present. (This was shortly after the Revolution of 1920 and railroad service in many sections of Mexico was uncertain. Service was maintained through Orizaba to Mexico City and from Mexico City to El Paso, however, with only occasional interruptions.)

As a locality for the collection of enemies of *Pseudococcus nipae*, Orizaba subsequently proved to be exceptionally satisfactory. Located on the main line of the Mexican railroad between the port of Vera Cruz and Mexico City, it is about 70 miles from the Gulf of Mexico, and at an altitude of about 4000 feet. Being on the east slope of the mountains that rise to 18,000 feet, it is subject to a heavy rainfall that extends through a much greater part of the year than in many sections of Mexico. Avocados were very abundant in that locality, nearly all of the gardens in the city and surrounding country having some trees, and in many instances they were growing almost semi-wild in clearings on the mountains and along the trails. Guavas were also abundant both in gardens and growing wild along the railroad tracks and in wastelands, so that to one living in the city of Orizaba, there would be easily accessible an abundance of host plants available for the mealybugs.

Preliminary observations were made in several nearby localities. On March 15, at El Potrero, about 25 miles from Orizaba, and at an elevation of only 2000 feet, *Pseudococcus nipae* was noticed on avocados but the infestation was very slight. A few *Hyperaspis* were secured from this infestation, however. At this time the

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mealybug infestation seemed very light also around Orizaba, but within two weeks local infestations were found so that it was possible to make satisfactory shipments of coccinellid larvae which later reared out as the *Hyperaspis silvestrii*.

#### COLLECTION AND SHIPPING OF *Hyperaspis* and *Curinus*

Soon after the middle of March the infestations of mealybugs at Orizaba had developed so that coccinellids could be obtained and the collecting and shipping of the beetles was begun and continued for a period of about six weeks. The mealybugs during this time fluctuated widely from week to week, appearing suddenly in small areas at times and then being quickly and completely cleared off by the coccinellids. Thus at times the coccinellids were obtained in good numbers without difficulty. On one occasion I found, half covered with vines, a small guava tree, two branches of which had been quite heavily infested but the tree was being very rapidly and efficiently cleaned by a swarm of the *Hyperaspis silvestrii*. I collected over 200 larvae of *silvestrii* from the two branches, a large part of them being full-grown, enough it would seem to account for the remaining mealybugs on this tree in a very short time. These larvae collected made up the most of one particular shipment to Honolulu.

In collecting colonies of *Hyperaspis* it soon became evident that more than one species were present, but no particular effort was made to segregate them in the shipments as they were of such similar habits that it seemed advisable to send them all to Hawaii. In subsequent rearings to the adult stage it appeared that *Hyperaspis silvestrii* had been much the most abundant species at the time the collections were made.

There was also a larger coccinellid sometimes found in the mealybug infestations although it appeared to be of very much less importance. This subsequently reared out as *Curinus coeruleus* (Muls.) and rather limited numbers were shipped to Honolulu.

At first, in collecting for shipment, eggs or small larvae were brought in from the field and fed on mealybugs until grown and then sent by express. Later on it seemed more desirable to wait until a few days before time to make a shipment and then to collect the larvae full-grown in the field. The method of preparing the larvae for shipment was exceedingly simple. Graniteware milk pails (usually one-quart size) were used, into which loose guava leaves and trash were placed. Some mealybugs were on the leaves although this was not essential as the larvae had about finished feeding and in any case there would not be enough mealybugs to last in such a container. Heavy muslin cloth was tied tightly over the top of the pails and these were then packed in especially made strong wooden boxes. About 50 *Hyperaspis* larvae were placed in each pail.

It was observed that some of the *Hyperaspis* larvae were themselves parasitized and that parasites might emerge from field-collected material. Mr. Fullaway later informed me that there was never any evidence that anything had escaped from the pails.

The total of 8 shipments of coccinellid material from Orizaba, March 27 to May 1, 1922, was: 720 *Hyperaspis silvestrii* larvae, 80 *Hyperaspis* sp. larvae, and 80 *Curinus coeruleus* larvae. From these there arrived alive in Honolulu 289 adult

*Hyperaspis silvestrii*, 27 *Hyperaspis* sp., and 37 *Curinus coeruleus*. *Hyperaspis silvestrii* and *Curinus coeruleus* were in part liberated and in part held in the insectary for rearing, where they bred successfully for distribution. They both became established and widespread in Hawaii, but whatever good they did at first was completely overshadowed by the work of the little parasite, *Pseudaphycus utilis*, which was sent to Honolulu at the same time from Orizaba.

#### *Pseudaphycus utilis* TIMBERLAKE AND ITS INTRODUCTION INTO HAWAII

It soon became apparent at Orizaba that there were several species of mealybugs mixed up in the infestations on guava and avocado from which I was collecting the *Hyperaspis*, also, that there were more than one species of *Hyperaspis*. So far as the *Hyperaspis* was concerned this was not of such great importance since these coccinellids fed somewhat indiscriminately on all of the mealybugs.

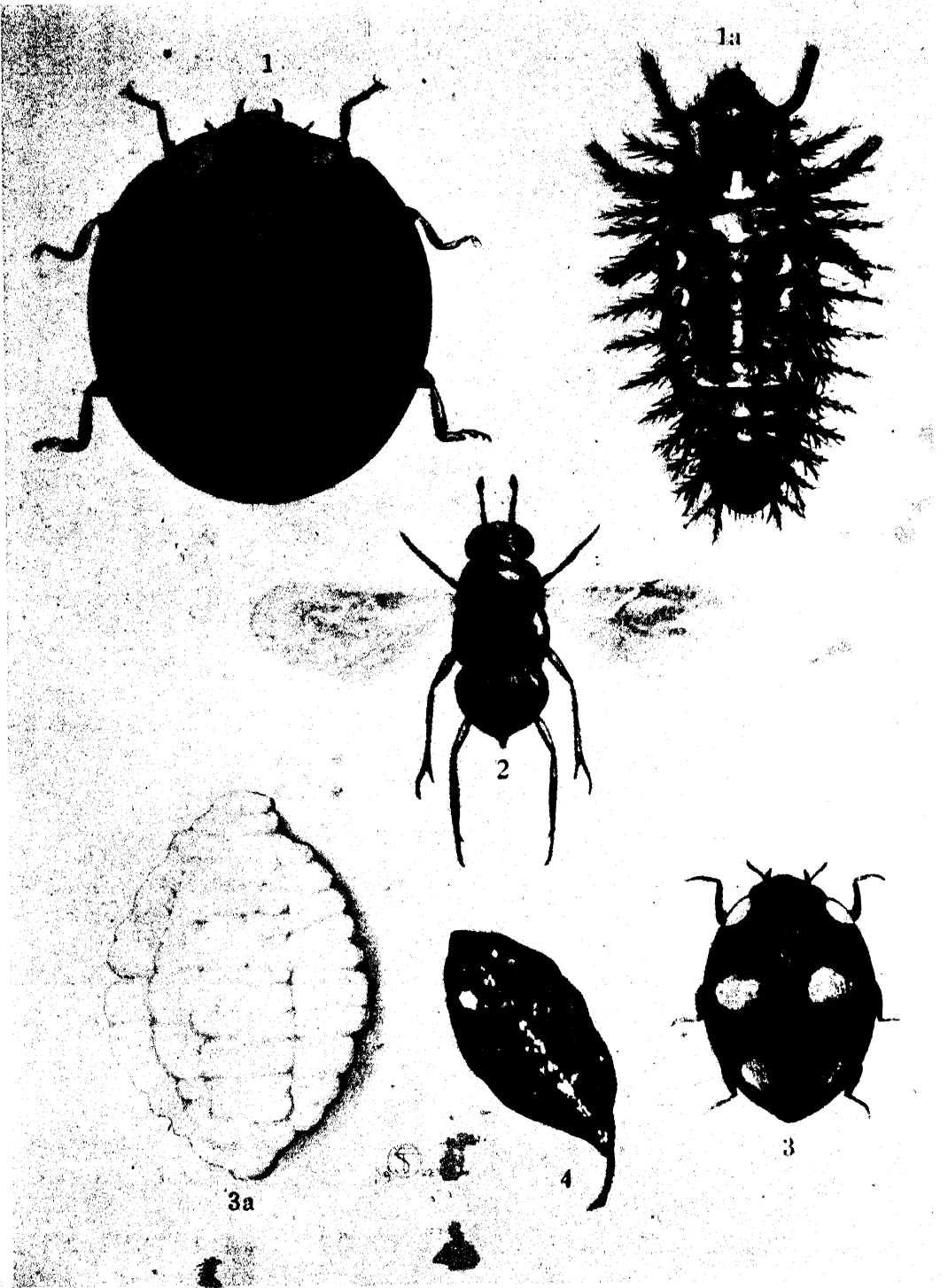
However, there were soon found to be several hymenopterous parasites attacking the several species of mealybugs and these in turn proved to be attacked by a number of hyperparasites comprising in all a somewhat complicated interrelationship. The last of the primary parasites to be noticed while I was working at Orizaba was the one which I referred to as a bright-yellow parasite on *Pseudococcus nipae*, and which was later identified as new and described by P. H. Timberlake as *Pseudaphycus utilis*.\*

Shipments of parasitized mealybugs were made in April 1922. They were mostly collected on the heavily infested tree from which the coccinellids were collected for shipment, adults of the bright-yellow parasite were observed and several caught. A few were reared out from a part of the material similar to that sent to Honolulu. Some of the material sent was from the scattering infestations previously mentioned and most of the mealybugs were found to contain parasite larvae if dissected.

From one lot of the parasitized material which was sent, Mr. Fullaway secured 23 females and 26 males of *Pseudaphycus utilis*. On the advice of Mr. Timberlake these were liberated directly in infestations of *Pseudococcus nipae* in Honolulu without attempting to rear them. One of these localities of liberation was a fig tree in a yard adjoining the Experiment Station, H.S.P.A., on Keeaumoku St. From this tree three adult parasites were recovered early in October of the same year, and was the first indication of the parasite becoming established.

I left Orizaba early in May and was located for several weeks at Cordoba, Vera Cruz, about 25 miles distant from Orizaba and at a much lower elevation, about 2500 feet. At this time in the vicinity of Cordoba, *Pseudococcus nipae* was conspicuous by its absence, although there was a great abundance of the favorite host plants. I made no further shipments of enemies of *Pseudococcus nipae*. Never in the next few years spent in various sections of tropical Mexico did I observe *Pseudococcus nipae* as abundant as it was at times during the six-week period at Orizaba in March and April, 1922. At Cordoba and at El Potrero in Vera Cruz, at altitudes from 1800 to 2500 feet, *nipae* was usually present in small numbers if searched for on guava and on avocado, but not sufficiently abundant to be notice-

\* Proceedings of the Hawaiian Entomological Society, 5: 323-326, Figs. 1-4, 1923.



Enemies of the avocado mealybug. (Courtesy of Board of Agriculture and Forestry.)

1. *Curinus coeruleus*. Adult beetle.

1a. *Curinus coeruleus*. Larva.

2. *Pseudaphycus utilis*. Parasite.

3. *Hyperaspis silvestrii*. Adult beetle.

3a. *Hyperaspis silvestrii*. Larva.

4. Leaf infested with mealybugs.

able. In no case did I find it abundant enough so that *Hyperaspis* could breed up to any extent. If carefully looked for at these lower elevations the *Pseudaphycus utilis* would be found parasitizing the *nipae*.

In view of its subsequent record in Hawaii, it would seem that *Pseudaphycus utilis* is the more important controlling factor at the lower elevations in tropical and subtropical Mexico, although I never would have thought so on the basis of observations made at Orizaba in the spring of 1922. From the standpoint of securing mealybug enemies for shipment it was fortunate that my first work was done in a particular locality where the control of *nipae* was somewhat irregular as was the case at Orizaba.

In about a year from the first recovery of *Pseudaphycus utilis* in Honolulu, the decline of *Pseudococcus nipae* began to attract attention, and by early 1924 it had practically disappeared on the island of Oahu where the first liberation of *Pseudaphycus utilis* had been made. In November 1924, I returned for a short time to the Islands and at that time it was still possible to find infestations on the islands of Maui and Hawaii, but the island of Oahu was entirely clean of *Pseudococcus nipae* and has remained so continuously since that time. In a very short time thereafter the infestations on the other islands of the group were cleaned off also. Ever since, the leaves of avocado remain clean, as do also the leaves of fig, mulberry, guava and other trees which were formerly always infested by *nipae*. It has been a most remarkable case, both as to rapidity of spread of the introduced parasite, and completeness of its work on the host insect, practically amounting to eradication. It seems reasonable to expect that under the conditions in Hawaii, *Pseudaphycus utilis* will continue alone to exert a complete control of the avocado mealybug.

#### OTHER MEALYBUG ENEMIES

In addition to *Pseudaphycus utilis* there were three other primary parasites in the mealybug infestations about Orizaba which were collected in some number and shipped to Honolulu.

*Allotropa* sp. (Platygasteridae). Mr. Fullaway reported that 475 females and 353 males of this species were reared out alive in Honolulu from material sent from Orizaba in March and April. They were released directly into the field.

*Gyranusa*, 2 species (Encyrtidae). Of these parasites 74 females and 16 males were reared out alive in Honolulu and released directly into the field.

None of these parasites appear to have become established in Hawaii, and I have always considered that their host was not *nipae*. There were several recognizable differences in the living mealybugs on the trees, and so far as I could determine at the time, my rearing of *Pseudaphycus utilis* was from *nipae* while the rearings of *Allotropa* were from what I took to be another species which I referred to as the buff mealybug. Oviposition was observed in the field by both the *Allotropa* and the *Pseudaphycus* in very young mealybugs, and even in the young stages the two mealybugs involved seemed to be distinct. However, specimens of what I called the buff mealybug, which were killed and sent for identification, were pronounced to be *Pseudococcus nipae*, as were also those which I considered to be the true *nipae*. The two species of *Gyranusa* were possibly also from still a third species of



mealybug, although in the limited time in which I was working on these there were many points which I did not determine definitely.

In addition to the coccinellids and the parasites mentioned there were also a number of insects found feeding in the mealybug infestations, which seemed to be of minor importance and no special effort was made to collect them. Among these was a scymnid, a syrphid (*Baccha*), an agromyzid (*Leucopis*) and a hemerobiid. Caution was advised in the case of the hemerobiid, in a letter of July 13, since they were observed at times to attack the coccinellids as well as the mealybugs.

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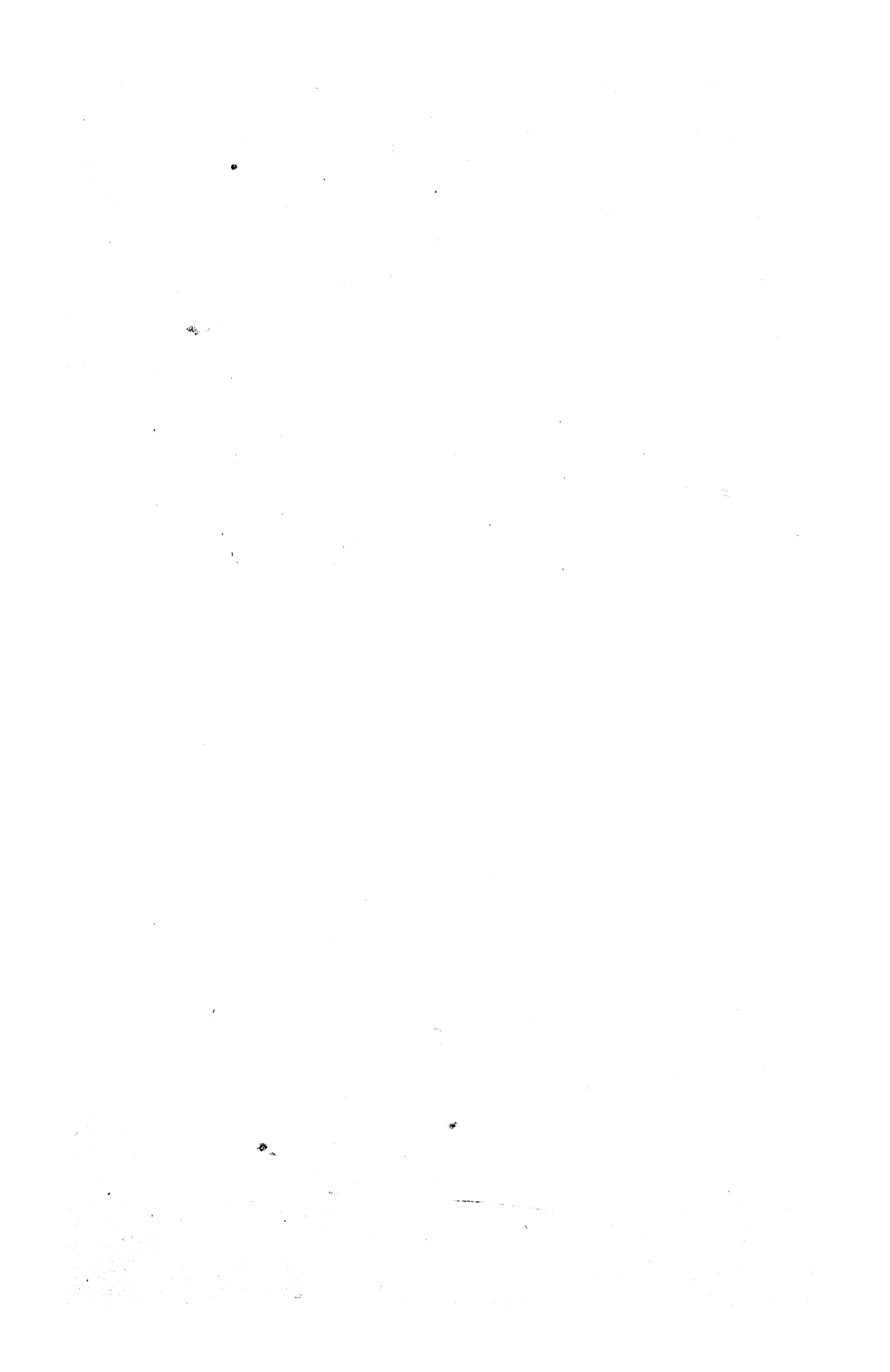
## Sugar Prices

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### 96° CENTRIFUGALS FOR THE PERIOD DECEMBER 20, 1937 TO MARCH 15, 1938

Date	Per pound	Per ton	Remarks
Dec. 20, 1937....	3.25¢	\$65.00	Cubas.
“ 21.....	3.20	64.00	Cubas.
Jan. 7, 1938....	3.23	64.60	Cubas.
“ 10.....	3.23	64.60	Philippines.
“ 12.....	3.25	65.00	Cubas.
“ 18.....	3.23	64.60	Cubas.
“ 19.....	3.20	64.00	Philippines.
Feb. 1.....	3.17	63.40	Cubas, 3.18; Philippines, 3.16.
“ 8.....	3.15	63.00	Philippines.
“ 10.....	3.13	62.60	Puerto Ricos.
“ 11.....	3.125	62.50	Philippines, 3.12; Puerto Ricos, 3.13.
“ 14.....	3.13	62.60	Puerto Ricos.
“ 16.....	3.17	63.40	Philippines.
“ 21.....	3.15	63.00	Puerto Ricos; Philippines.
“ 24.....	3.13	62.60	Philippines.
Mar. 1.....	3.15	63.00	Philippines.
“ 3.....	3.10	62.00	Puerto Ricos.
“ 7.....	3.065	61.30	Puerto Ricos, 3.07, 3.06.
“ 10.....	3.07	61.40	Philippines.
“ 11.....	3.085	61.70	Philippines, 3.10, 3.07.
“ 14.....	3.0667	61.334	Cubas, 3.08; Puerto Ricos, 3.07; Philippines, 3.05.
“ 15.....	3.035	60.70	Philippines, 3.04, 3.03.

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# THE HAWAIIAN PLANTERS' RECORD

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*A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.*

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## **In This Issue:**

### *Some Aspects of the Chemistry of Soil Colloids:*

A brief discussion is presented which clarifies an understanding of the properties of soil colloids in their relation to commonly observed phenomena as may be noted by the layman but more particularly as encountered by the worker in agricultural soil research.

The discussion leads to an exposition of the modern concept of the inorganic base exchange properties of soils in that the seat of exchange resides in that soil fraction consisting of crystalline silicates of iron and aluminum. And finally that base exchange is essentially a property of molecules.

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### *Sugar Cane Beetle Borer Trapping Experiments:*

A year's systematic trapping of two small areas at Kailua shows that, probably due to a number of factors such as beetle migration and reduced effectiveness of parasites, borer population has not been reduced. Traps of split canes are most attractive during the first two weeks, and after being discarded should be destroyed to prevent the emergence of a new generation of borers developing from the eggs laid in the trap pieces.

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### *Non-Replaceable Potash Fixation:*

The fixation of potash in agricultural lands may be enhanced by artificial fertilization. The fraction so fixed may be replaceable and quite available to plant life.

However, not all fixed soil potash is necessarily present in a form which makes it a reserve supply capable of immediate utilization upon vegetative demand.

A discussion is presented in support of these premises. It is followed by a description of various conditions existing in the soil which may contribute to or favor any one of several types of soil potash fixation.

An adaptation of modern laboratory research to a practical R.C.M. study of the subject is offered in minute detail.

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*Fertilizer Analysis by the Spectrograph:*

Results of the spectrographic analysis of twelve standard commercial fertilizers are reported. This type of analysis gives information on the mineral constitution of the fertilizers, extremely small traces of many metals being detectable.

Some twenty-one different metallic and semi-metallic elements were encountered in the course of the investigation.

The results are given semi-quantitatively. Of particular interest is the information on the occurrence of the less common plant nutrients in fertilizers—the so-called “less essential” or minor elements.

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*Selenium I:*

Specific vegetation grown on soils of volcanic origin frequently contain selenium. Grazing animals, swine and poultry which consume seleniferous food are affected by the selenium taken into their systems. Diseases develop, many of which prove fatal.

Proof of the causal factor (selenium) in diseases of farm stock has been established but recently.

This paper presents an introductory discussion of the subject as a part of the research now in progress.

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*Some Insect and Other Animal Pests in Hawaii Not Under Satisfactory Biological Control:*

While many insect pests in the Hawaiian Islands have been brought under excellent control by the biological method, there are still a number that have no very effective enemies and therefore do considerable damage. This article reviews some three dozen of such pests together with natural enemies that might be introduced here to help control them.

The literature cited contains over one hundred titles.

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## Some Aspects of the Chemistry of Soil Colloids\*

By L. A. DEAN

Hawaii Agricultural Experiment Station

Among the outstanding properties of soils having large numbers of particles in a fine state of subdivision are stickiness and liability to puddle when wet, and a tendency to crack and to form hard, brick-like clods when dry. Even those who are not acquainted with agricultural chemistry have observed that, during wet weather, doors are more apt to stick to door jambs; this is often the result of these properties of the clay or colloidal particles whereby the soil moves the foundations of the building.

Soils contain two types of colloids: (1) the clay, and (2) the humus. The clay is an electronegative *suspensoid*, the humus, an electronegative *emulsoid*. We might digress at this point to discuss briefly a few considerations in the classification of colloids. Zsigmondy divided colloids into two classes, those which are reversible and those which are irreversible. No sharp line can be drawn between these two classes for there are many transition cases. Gelatin typifies a reversible colloid; it may be put into solution merely by the addition of water. In this case there is no simple boundary between the phases; when water is added to dried gelatin considerable quantities of the water dissolve in the gelatin forming what might crudely be termed liquid particles (the particles become hydrated). For this reason the term "emulsoid" is often applied to this type of colloid; others prefer the terms "hydrophile" (water-loving) and "lyophile" (solution-loving). Let us now consider a solution of iron oxide particles in water as an example of an irreversible colloid. These particles may readily be coagulated and separated sharply from dilute solution. Chemical or electrical energy is then necessary to return them to colloidal solution. The term "suspensoid" is often applied to this type of colloid, as well as the terms "hydrophobe" (water-hating) or "lyophobe" (solution-hating).

Modern work with soils has indicated that the colloidal material is present in the form of a gel coating over the surface of the larger particles of primary minerals. The obvious result is that the soil as a whole is impressed by the properties of the gel coating, to an extent dependent on the proportion of colloid present. A heavy clay soil should, therefore, be regarded as consisting of a relatively small proportion of coarse and medium particles with so thick a gel coating of colloidal particles that the properties of the latter dominate the soil as a whole. A more practical example might well be the so-called abnormal soils of the Hamakua coast, the properties of which do not seem so out-of-line if their coatings are considered as predominately organic colloids of the emulsoid type.

Aside from a consideration of the physical relations and properties of soils resulting from the presence of particles in a fine state of subdivision, the role of these

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\* Presented at the meeting of the Hawaiian Section of the American Chemical Society, April 21, 1938.

soils in relation to the conservation of essential elements or plant foods and to their uptake by plants is very important. The relation of the important properties to the degree of subdivision of soil particles is given in Chart I, adapted from Truog.

The statement is often made that the most important property of soil colloids is their high specific surface. The law of Guldberg and Waage or, as it is commonly called, "the law of mass action," states, essentially, that the rate at which a substance will react is proportional to its "active mass." Soil chemists have often carried this law one step further and stated that the reaction rate is proportional to the "active surface," which might be considered essentially Wenzel's Law, which states that "the reaction velocity of solids with liquids is proportional to the area of contact." The following may be listed as the roles of the active surface of the soils:

- (1) The solution of the essential elements in order that the needs of plants may be supplied.
- (2) The removal of the soluble essential elements from a liquid to a solid phase in order that they may not be lost by leaching, especially when soluble fertilizers are applied.

#### *The Composition of Inorganic Soil Colloids:*

In 1862 Thomas Graham coined the word "colloid" from a Greek word meaning glue to identify those substances which, in solution, do not diffuse through a membrane. He named those substances which, when in solution, would diffuse through a parchment membrane as "crystalloids." This terminology in later years proved to be singularly unfortunate, for a common conception was developed that colloidal particles were amorphous masses. For many years it was popularly believed that the inorganic soil colloids or clays were mixtures of amorphous masses of iron oxide, aluminum oxide, titanium oxide, and silica. Also, the base exchange properties were attributed to adsorption on the surfaces of the particles. These beliefs were based mainly upon an inaccurate knowledge of the composition of clay constituents gathered from numerous ultimate chemical analyses.

The application of X-rays to the study of crystal structure soon showed that a number of materials commonly described as amorphous were crystalline. A notable example is cellulose which is now considered, by many, to be crystalline. In fact, many today argue that all solid matter is either crystalline or a solid solution (super-cooled liquid) and the crystalline state is defined as a systematic arrangement of either molecules, ions, or atoms. That clays are crystalline in nature was first demonstrated in 1928 by Ross, whose work was followed closely by that of Hendricks and Fry. Today it is accepted by many investigators that the inorganic soil colloids or clays are mixtures of definite crystalline compounds.

The base exchange properties of soils are analogous to those of the artificial and natural zeolites which are used for softening hard water. This base exchange is considered as being a simple double decomposition reaction following the laws of stoichiometrical chemistry. The process of softening water is simply the conversion of the calcium salts of the hard water into sodium salts. This entails the changing of the zeolites from sodium to calcium salts. For many years it has been observed that only soil material in a fine state of subdivision has base exchange properties. However, it was not until the results of more recent clay investigations pointed out

## The Subdivision of Matter and Resulting Properties

	↓	↓	↓	↓	↓
Size of particles, 1,000,000 $\mu\mu$ .....	1,000 $\mu\mu$ .....	100 $\mu\mu$ .....	1 $\mu\mu$ .....	0.1 $\mu\mu$ .....	
Rel. no. particles.....	1.....	$10^9$ .....	$10^{12}$ .....	$10^{15}$ .....	$10^{21}$ .....
Rel. surface.....	1.....	1,000.....	10,000.....	1,000,000.....	10,000,000.....
	↑ Coarse suspensions	↑ Colloidal suspensions	↑ Colloidal solutions	↑ Molecular solutions	

Appearance	Very cloudy	Turbid	Clear	Clear
Particles observed	With naked eye	With microscope	With ultramicroscope	Cannot be observed
Rate of settling	Quickly or overnight	Slowly or not at all	Do not settle	Do not settle
Particles separated	With filter paper	With clay filter	With ultrafilter	Not by filtration
Diffusion and dialysis	None	None	None or very little	Very high
Adsorption	Low	Considerable	Very high	None
Rate of reaction	Low	Moderate	High	Almost instantaneous
Form on evaporation	Loose powders	Powders and gels	Gels	Crystals
Soil separates	$\leftarrow$ Sand $\leftarrow$ $\leftarrow$ Silt $\leftarrow$ $\leftarrow$ Clay $\rightarrow$ 50,000 $\mu\mu$ 5,000 $\mu\mu$	$\leftarrow$ Clay $\rightarrow$ $\leftarrow$ Ultra Clay $\rightarrow$ <b>Soil Colloids</b>		

Limit of microscope (ultra violet light)..... 100  $\mu\mu$       Diameter pores of hardened filter paper..... 1,500  $\mu\mu$  to 2,200  $\mu\mu$

Limit of ultramicroscope..... 10  $\mu\mu$       Diameter pores Chamberland filter..... 200  $\mu\mu$  to 400  $\mu\mu$

Limit of ultrafilter..... 1  $\mu\mu$       Diameter of bacteria..... 500  $\mu\mu$  to 1,200  $\mu\mu$

Brownian movement starts at..... 5,000  $\mu\mu$       Diameter 200 mesh particles..... 74,000  $\mu\mu$ .

A cube 1 cm. on side divided to cubes 1  $\mu\mu$  on side gives a surface of  $1\frac{1}{2}$  acres.

## CHART I.

Adapted from Truog, E., Journal of the American Society of Agronomy, 17: page 281, 1925.



what compounds made up soil colloids that it was possible to consider base exchange anything but a property of the surfaces of electronegative colloids. It is now quite generally accepted that much of the base exchange of soils finds its seat in the so-called clay minerals which are crystalline aluminum or iron silicates, the base exchange being a property of the molecules. It would thus appear that oftentimes the chemistry of the composition of colloidal particles is an important consideration.

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## Trapping Sugar Cane Beetle Borers at Kailua\*

By R. H. VAN ZWALUWENBURG

To determine if the population of the sugar cane beetle borer (*Rhabdocnemis obscura*) can effectively be reduced by intensive trapping under the conditions found on windward Oahu, J. S. Rosa and the writer, with the cooperation of the Genetics department, conducted trapping experiments for a year in two fields at the Kailua substation. Standardized traps were used throughout, consisting of 30 split pieces of POJ 2878 cane; the bundles were wrapped in clean sacking with the ends tucked in loosely to make access easy for the beetles. The traps were set out early each month at fixed stations which probably varied in location not more than 15 feet at any time during the year. Collections from each set of traps were made and recorded at weekly intervals for five weeks. First collections from new traps were sometimes made on the same day that the last collections were made from five-week old ones. In such cases there seemed to be no reduction of catch in the old traps due to greater attraction by the new; old traps at best attracted very few beetles. Ten traps were maintained in each of the following fields:

*Field ADA:* Located in a small valley notorious for high borer population, this field contains 0.59 acre of small variety plots interplanted with POJ 2878. It was an old ratoon when last cut in April 1936 and had been abandoned. Random trapping to get material for another experiment had been carried on in this field for about six weeks before the experiment began. Across the road, to the east of ADA, is Field ADC, an area of 2.5 acres last cut on May 11-12, 1937, and still maintained as a ratoon.

*Field G-6:* This is about two acres of small variety plots interplanted with POJ 2878; it is first ratoon, last cut in June 1936. About midsummer of 1937 it was abandoned and no further attention was given it by the agriculturists. No trapping was done prior to the start of the experiment. The trapping stations in this field were located along the eastern edge of the field next to a small stream, protected from prevailing winds by a high, wooded bank. Three of the stations were in a low area which was flooded once or twice during the year.

Between February 20, 1937, when the first collections were made, and March 9, 1938, when the last collection was made from traps set out February 2, 1938, a total of 27,027 beetles was captured; 16,476 were from Field ADA, and 10,551 from Field G-6. Omitting the figures from the February 1937 traps (because of incompleteness), ADA yielded 14,755 beetles (7,535 males and 7,220, or 48.9 per cent females), and G-6, 9,449 beetles (5,004 males and 4,445, or 47.0 per cent females). In the following summary of the catch in each field, the figures are the average total per trap of five collections from traps set out in the months indicated; these figures are shown graphically in Fig. 1.

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\* The statistical evaluation of the conclusions reached in this study was made by L. R. Smith and others of the Agricultural department.

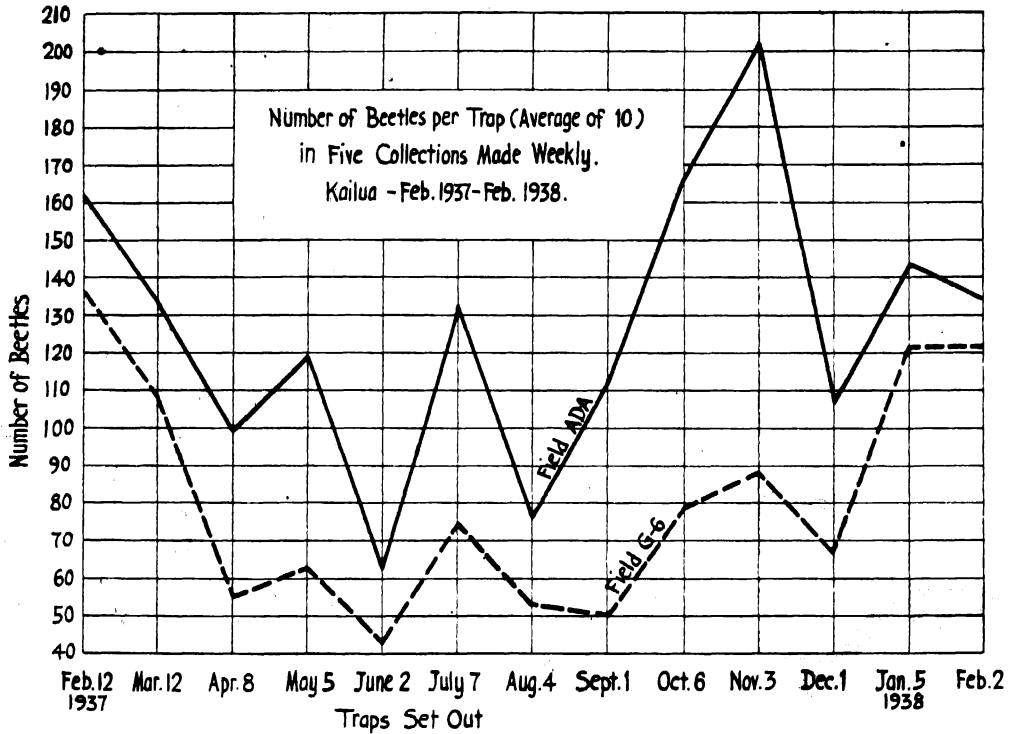


Fig. 1

Month in which traps were set out	Field G-6			Field ADA			Avg. mean temp. F.
	Total	Male	Female	Total	Male	Female	
February 1937	136.6	?	?	161.4	?	?	68.3
March	107.5	67.5	39.9	132.9	69.8	62.2	72.4
April	55.0	33.4	21.0	99.5	47.1	51.4	72.8
May	62.8	33.7	29.1	119.4	55.8	62.9	73.5
June	42.6	23.7	18.7	62.5	31.1	31.4	75.9
July	74.3	30.8	43.5	131.7	56.9	74.8	76.2
August	52.3	23.1	28.8	75.8	37.6	38.2	76.1
September	49.8	23.0	26.5	112.1	51.8	57.7	75.8
October	78.1	36.0	41.7	167.0	85.4	80.3	75.4
November	87.8	41.9	44.7	202.8	109.1	93.3	73.2
December	66.0	37.1	22.8	106.0	55.7	50.1	70.1
January 1938	121.2	64.4	55.3	143.1	82.8	59.6	71.8
February	121.1	58.9	61.2	133.4	71.9	60.5	71.7

These figures seem to show, in spite of wide variations, a trend toward a greater number of beetles in winter than in summer. Heavy catches of beetles seem to be associated with hot, still, humid weather, but unfortunately relative humidity data for Kailua are not available for correlation with our figures.

To reduce the borer population to a reasonable level it is necessary to attract the beetles already accumulated in the field when trapping begins, as well as those which form the natural month-to-month increase in the population. This requires that traps be more attractive to the beetles than the standing, broken and rat-eaten

cane present, and that there be no considerable immigration of beetles from outside areas.

From the figures tabulated above, it is apparent that the year's trapping failed to reduce greatly the borer population in either of the experimental fields. In ADA, where preliminary trapping may have reduced the accumulated population already present when the experiment began, the difference between the first and last totals (February 1937 and February 1938) is greater than in G-6 where the absence of preliminary trapping should presumably have resulted in the larger before-and-after difference.

One factor, concerning which little definite is known, and which may be more important than originally believed, is the distance to which adult borers migrate, or are attracted, under field conditions. Marked beetles have been recovered in traps at a distance of 650 feet from standing cane in which they had been released less than six weeks before. Recently, beetles of both sexes have been trapped under circumstances which make it certain they had left standing cane and travelled across open areas for distances up to 150 feet. In some cases there was no cane whatever (except the trap itself) in the direction they had traveled, and it seems probable that at least a few beetles are leaving cane areas more or less continually.

If cane is disturbed, as in harvesting, or if no cane is present, it is to be expected that beetles may migrate considerable distances. This is suggested by the following figures from ADA, in which the increased catch in the week-old traps on May 12 may have resulted from cutting the nearby ADC (without burning) on May 11th and 12th:

Traps set out April 8		Traps set out May 5	
April 14 .....	21.7 beetles per trap	May 12 .....	44.8 beetles per trap
April 21 .....	28.9 beetles per trap	May 19 .....	33.4 beetles per trap
April 29 .....	29.8 beetles per trap	May 26 .....	21.0 beetles per trap
May 5 .....	13.3 beetles per trap	June 2 .....	14.3 beetles per trap
May 12 .....	5.8 beetles per trap	June 9 .....	5.9 beetles per trap

That the effectiveness of the *Ceromasia* parasite of the borer is reduced by cane falling over, or by heavy trash and weed cover, is well recognized. To what extent the tachinid's effectiveness was thus impaired in this experiment is not known; but both fields were untended for most of the experiment—honohono (*Commelina*) thrived, and the cane lodged badly. The result was a condition unfavorable to effective control by parasites, to a degree that would not have occurred under plantation routine.

Traps show a definite loss of attraction for beetles after the second week (see Fig. 2). The following data are a summary of results from both fields; the first collections were made when traps were one week old, the second when they were two weeks old, etc.:

	Number of beetles	Per cent of total
1st collection .....	7552	31.0
2nd collection .....	8320	34.2
3rd collection .....	5039	20.7
4th collection .....	2318	9.5
5th collection .....	1075	4.4

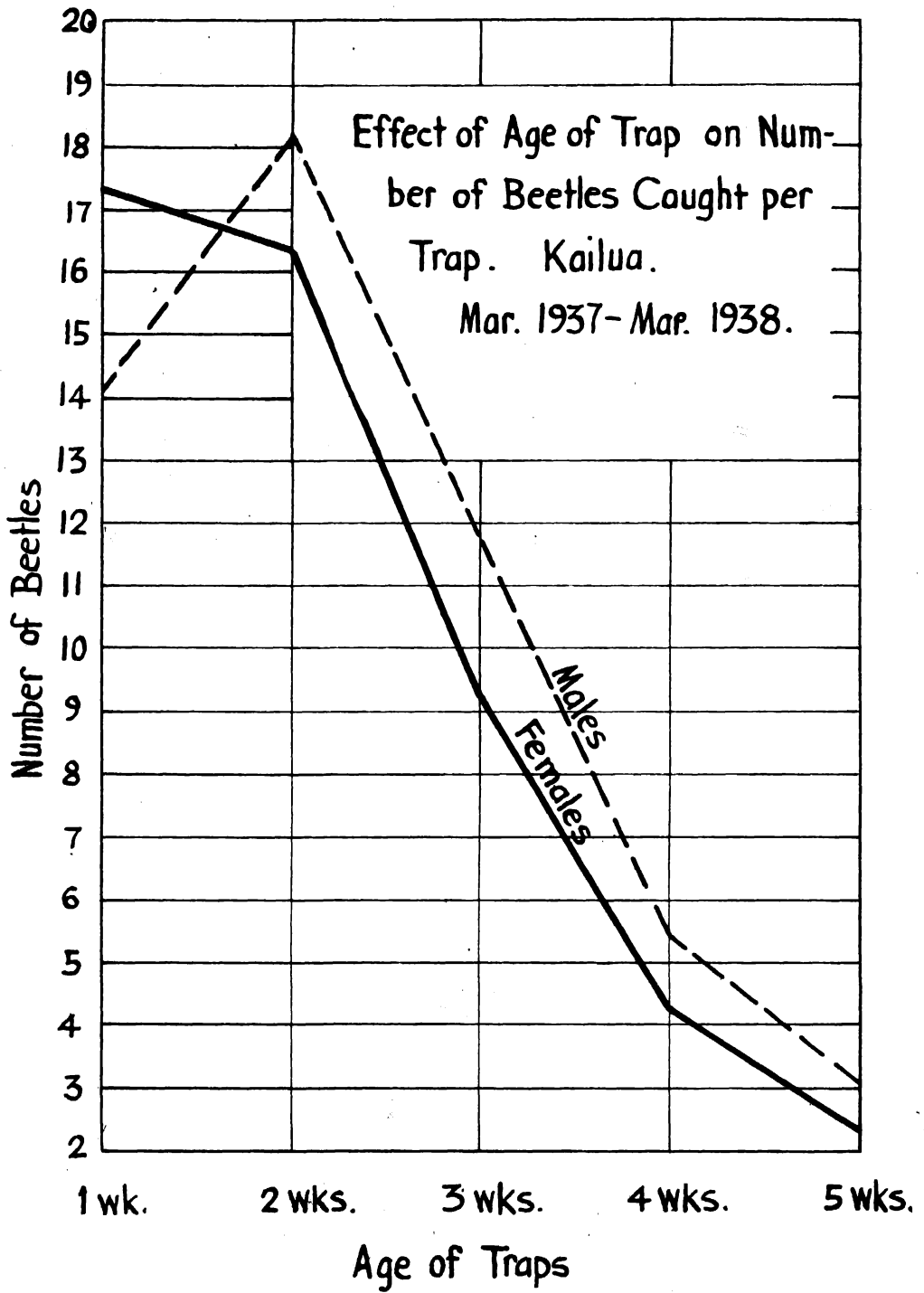


Fig. 2

Nearly two-thirds of all the beetles were caught in the first two weeks, and 86 per cent in the first three. By sex, the catch was :

	Number of males	Number of females	Per cent females
1st collection .....	3396	4156	55.0
2nd collection .....	4388	3932	47.2
3rd collection .....	2823	2216	43.9
4th collection .....	1303	1015	43.7
5th collection .....	629	446	41.4

In general, the females outnumbered the males during the first week, although in a few cases females predominated in later collections. The increase in beetles of both sexes in the two-week old traps was also fairly consistent, and was due to a large increase of males. Whether males are less strongly attracted to the traps, or are really attracted by the females present, rather than by the traps themselves, is not apparent.

There is a moderate trend, without statistical significance, for the ratio of females to males to be higher in summer and fall than in winter (see Fig. 3). The following figures indicate the numbers captured within each calendar month (not the month in which the traps were set out) :

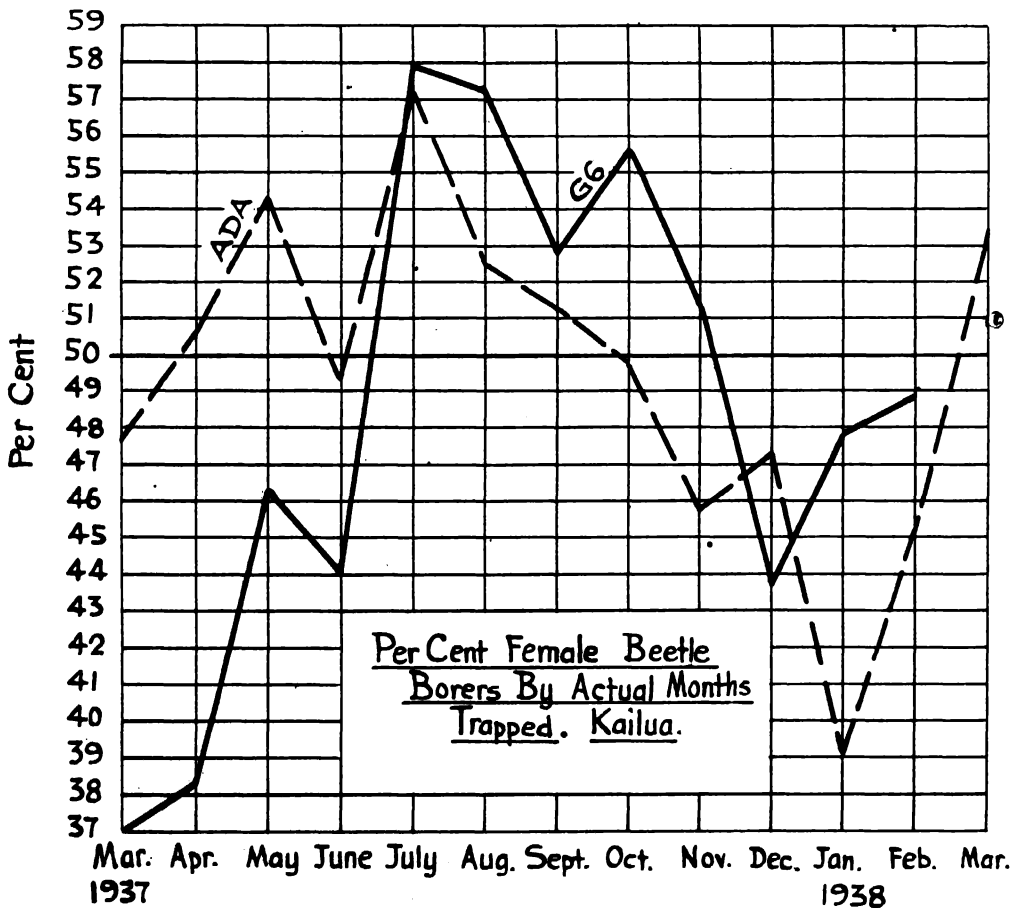


Fig. 3

	Field G-6			Field ADA		
	Males	Females	Per cent females	Males	Females	Per cent females
March 1937 ....	846	497	37.0	607	556	47.8
April .....	388	241	38.3	470	482	50.6
May .....	342	295	46.3	536	641	54.4
June .....	264	209	44.1	401	390	49.3
July .....	288	397	57.9	508	682	57.3
August .....	220	295	57.2	378	419	52.5
September .....	260	291	52.8	569	600	51.3
October .....	308	386	55.6	714	710	49.8
November .....	432	457	51.4	1131	956	45.8
December .....	353	274	43.7	542	490	47.4
January 1938 ...	511	470	47.9	696	497	39.1
February .....	694	666	48.9	823	683	45.3
March .....	...	...	...	497	571	53.4
April .....	...	...	...	743	848	53.2

The greatest benefit from trapping is to be expected only if traps are destroyed as soon as they no longer attract borers. A new generation of beetles will develop in canes left lying in the field, the result of eggs laid while the traps were still attractive to the females. In the laboratory, fourteen beetles completed their development in an old trap within 15 weeks of its first being set out, in spite of the extreme dryness of the cane. In the field, with better moisture conditions, even more borers might have reached maturity from similar discarded traps.

Weekly examinations were made by F. A. Bianchi of female beetles collected from September into March, to determine the number of mature eggs present in each. The average was 4.2 eggs per female; and that comparatively few eggs mature at a time is to be expected among insects which lay large numbers of eggs over a long period (upwards of 600 in about a year in the case of this beetle). The number of mature eggs varied from 0 to 17. No seasonal difference in egg complement could be detected for the period during which examinations were made, nor were females from fresh traps better or worse supplied with mature eggs than those from old traps.

#### CONCLUSIONS

1. A year's trapping apparently failed to reduce the borer population to any marked extent. This may have been due to one or more causes: migration of beetles from outside areas; failure of the traps to attract borers in competition with broken and rat-eaten cane; or the probably reduced effectiveness of the tachinid parasite under the conditions of the experiment.

2. More beetles were usually attracted to traps during the second week than at any other period. The catch obtained in the fourth and fifth weeks was so poor as to suggest that more beetles might have been collected if traps had been renewed every three weeks instead of every five.

3. Although the figures show an apparently higher catch of beetles in winter than in summer, such a conclusion is contradicted by evidence obtained so far in a second year of trapping. We believe one or more additional, unrecognized factors influence the borer population to a degree perhaps equal to that of the seasonal influence.

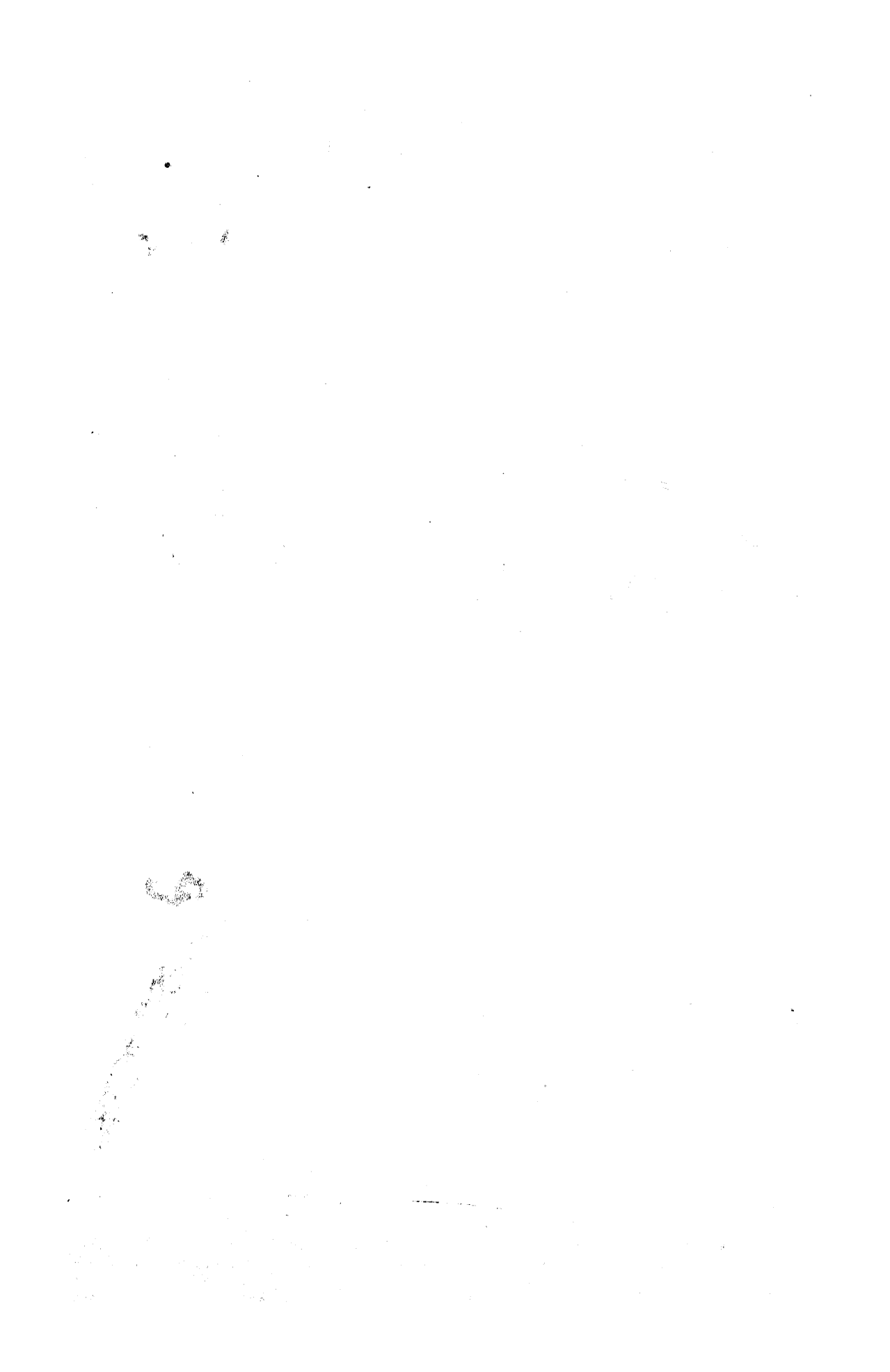
4. Female beetles are most strongly attracted to traps during the first week; males, during the second week.

5. The ratio of females to males tends to be somewhat higher during the summer months, although the trend is not statistically significant.

6. No correlation was apparent between borer population and either temperature or rainfall; but, because it takes from three to four, or more, months for this insect to develop from egg to adult, a lag is to be expected in any correlation between population and the climatic conditions operative some months before.

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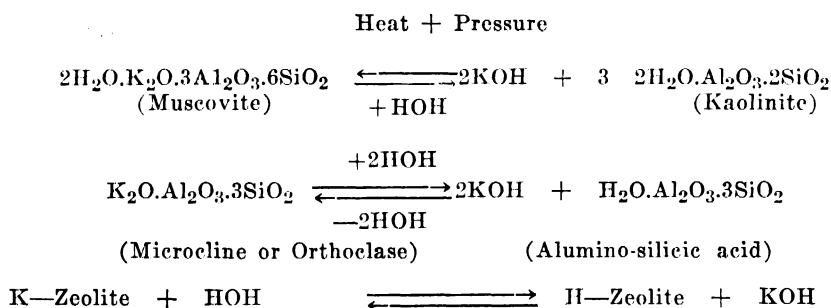
## Non-Replaceable Potash Fixation

By CLARENCE LYMAN\*

Potassium occurs in soils in forms which are water soluble, those from which it is replaceable, and largely as the silicate minerals which are predominately the feldspars (orthoclase and microcline), and the micas (muscovite and biotite). The potassium so present, like phosphorus, may be classified as readily available and difficultly available and, with the exception of the soluble portion, is said to be fixed.

Into the category of the readily available potassium falls the soluble form and that held in the base exchange material. The difficultly available forms of potassium include the minerals from which the nutrient cannot be replaced by a weak acid or a salt solution, but from which the potash is only slowly available to the plant in the order of biotite, orthoclase, muscovite, and microcline (7) and others, in amounts insufficient for proper growth.

The availability of essential soil elements being a relative matter, it is conceivable that the liberation of potash by the decomposition and hydrolysis of the potassium-bearing minerals can be reversed, as shown in the following empirical reactions, by the presence in the soil solution of an excess of potash such as results subsequent to fertilization:



Such reactions have long been considered outlets for the stabilization of the potassium balance in soils where leaching is not a preponderant factor.

This is substantiated by the work of Volk (12), who showed that under meteorological conditions of alternate wetting and drying, the readily available potassium in some soils becomes fixed to some degree in a non-replaceable form. When these soils were kept continually moist, however, very little fixation of this kind took place.

To facilitate discussion, the term "potash fixation" as used throughout the remainder of this paper will refer to the non-replaceable form of fixation.

By means of mineralogical, chemical, and X-ray analyses of a soil possessing high potash fixing properties, Volk concluded that fixation of this constituent resulted when a portion of the applied potash reacted with some of the colloidal alumi-

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\* Senior, University of Hawaii. Through special arrangements with the University, the experimental work reported in this paper was entirely confined to the direction of Dr. F. E. Hance, Chemist, Experiment Station, H.S.P.A.

num silicates present to form muscovite as a secondary mineral. This conclusion is not accepted by all soil investigators (3).

Volk has demonstrated that the amount of potash fixed varies with each soil and between the limits of zero per cent and 100 per cent of that added. The factors that affect the percentage of fixation in a given soil are shown to be the temperature of drying, the number of alternate wettings and dryings, the form of the potassium compound added (12), the amount of potash added (12, 10), and in some cases, the amount of calcium and magnesium present (12, 3, 5, 6, 10).

Preliminary work involving a number of potash, lime, and phosphate fertilization practices (Table II) and the extensive research of the highly conflicting literature indicate an absence of any general connection between the effects of non-potash fertilizers on a series of soils and the resultant fixation of potash or its liberation to the replaceable form.

On certain soils lime decreases the solubility of the non-replaceable potassium, while on others no effect (12, 9, 5), or a slight liberative effect is evidenced (1).

A conclusion which may be drawn from the divergent findings of Volk (12), Joffe and Kolodny (3), and Abel and Magistad (1), is one suggested by the work of the last two and by the findings of Peech and Bradfield (9). This is the highly probable effect of the fertilizer compounds on the base exchange material of the soils, the pH subsequent to fertilization, and the degrees of antagonism and common-ion effect.

For the purposes of comparison, and to cover as wide a range of fixation as possible, samples of local and mainland soils were obtained. Sources of sugar cane soils were the Waipio, Manoa, and Hilo substations of the Experiment Station, H.S.P.A., and cultivated and uncultivated Olaa areas. In addition, a sample of Superior clay collected in Ashland, Wisconsin; one of Miami silt loam from Dane County, Wisconsin; a series of samples from a profile of Manana silty clay loam taken near Waialua, Oahu; a residual Kohala soil extremely high in readily available potash; and a Kona coffee area soil were obtained.\* Of these last named, the local ones were all from uncultivated areas.

Ten-gram samples of the soils were impregnated with potash in the form of a solution of the chloride, to the extent of 1,400 pounds per acre-foot of 2.5 million pounds of weight.† These were then subjected to stimulated atmospheric conditions of alternate wetting and drying by being set in a constant temperature water bath adjusted to maintain a temperature of 70° C.,‡ and on reaching dryness, dampened with measured volumes of distilled water. For a maximum fixation at this temperature, the procedure was repeated for a total of ten dryings, although tests show that

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\* The writer is indebted to Dr. L. A. Dean of the Hawaii Agricultural Experiment Station for contributing these soils, of which the local samples, excepting that from Kona, were collected by the U. S. Department of Agriculture Soil Survey party.

† This rate of fertilization was arbitrarily chosen to keep the maximum amount of available potash within the maximum limits of the R.C.M. of determination without necessitating the dilution of the extract.

‡ It should be noted here that the temperature used is not far-fetched, for, when actually determined, the surface soil of the Makiki field was found to be heated to a temperature greater than 65° C.

from 60 per cent to 84 per cent of the amount fixed is so removed from the available class by a single drying.

Using a ratio of 1 ml. of water to each gram of impregnated soil "weathered" in a 250-ml. beaker, the period of heating necessary for drying to friability was found to be about an hour.

In duplicate the readily available potassium was then determined volumetrically by the permanganate titration of the sodium cobalti-nitrite precipitate (13), and turbidimetrically by the recently modified method for the rapid determination of potash in soils. (Chemistry Department, Experiment Station, H.S.P.A.)

As a basis for determining the per cent of the total readily available potash present that became fixed as a result of the weathering process, blanks were prepared by adding the same amount of potash, in the form of a highly concentrated solution, to the required amount of the extracting solution used.\* Care was taken to keep the total volume of the mixture to that necessary to maintain the soil-water ratio of each procedure. The mixture was then added to other portions of the same soil samples, followed by the immediate extraction and subsequent determination of the replaced potassium.

Before satisfactorily comparable results could be obtained, a number of refinements of the procedure for the turbidimetric analysis were found to be necessary.

Due to the inconsistency of the volume-weight method of measuring soil samples, analyses by this means were conducted on weighed samples.

In making turbidimetric readings by the conventional method, the failure to note more than one of the various acceptable readings obtainable with varied aliquots of extract introduced deviations of as much as 125 pounds of potash per acre-foot. Similarly, the failure to differentiate between a high 2 reading and a low 3 reading was found to increase errors between 14.2 per cent and 18.1 per cent.

It was originally felt that it would be necessary to employ a special potash chart to overcome the latter form of errors, and several of these, having less divergence in the thicknesses of the successive lines, were prepared. Later, however, a system of cross checking on the data sheet was devised and found to be entirely satisfactory. By this system, all successive aliquots giving acceptable readings in the range of a low 2 to a high 3 are noted, and the mean of their values in terms of 2 and 3 readings calculated. Results so obtained closely approximate the actual in pounds per acre-foot as determined with standard solutions.

With the incorporation of these refinements in the turbidimetric procedure designed by E. K. Hamamura,† the results shown in Table I were obtained.

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\* All extracts analysed by the volumetric method were prepared by using a 1 Normal solution of ammonium acetate adjusted to a pH of 6.8 and applied in a soil-water ratio of 15 ml. per gram.

† Assistant Chemist, Experiment Station, H.S.P.A.

TABLE I

## SOIL SAMPLES INCLUDE:

Manana Silty Clay Loam (MnDK), Hilo Substation (H), Kona Coffee area (K),  
Kohala Residual (KOH), and Waipio Substation (W)

Sample	Per cent fixation by titration	Per cent fixation by turbidimetry
MnDK 1000 .....	18.8	19.5
MnDK 1001 .....	18.1	17.5
MnDK 1002 (Hardpan) .....	11.3	18.7
MnDK 1003 .....	17.3	18.7
MnDK Hardpan duplicate at depth of 1001 .....	15.2	10.5
MnDK Partly decomposed rock at 30 feet .....	22.1	22.0
H 12523 .....	17.0	14.3
H 12524 .....	20.0	18.7
K .....	00.0	00.0
W Field 37, surface .....	00.0	00.0
KOH .....	00.0	00.0

The results tabulated above are from a long series of determinations, many of which were discarded due to extreme variations caused by the need for the refinements in the turbidimetric procedure described elsewhere. Table I is meant to manifest the practicability of the use of the turbidimetric procedure under the proper conditions of control.

With proof that the degree of potash fixation in soils could be satisfactorily determined by means of the Rapid Chemical Method of the Experiment Station, H.S.P.A., an attempt was made to adapt the procedure used in the research laboratory to the plantation laboratory. The greatest problem in this adaptation was obviously the regulation of the temperature of "weathering" to standard conditions without involving the use of an expensive constant temperature water bath such as is available at the Station. A study of the situation revealed that the heating equipment possessed by the R.C.M. laboratories of the agriculture departments of the plantations was for the most part limited to one of the several types of hot plates supplied by the Chemistry department of the Station. Each type was found to have a different capacity, correspondent to the variant voltages maintained by each plantation.

An attempt was made, therefore, to correlate the degree of fixation with the temperature of heating. A number of samples were placed on an asbestos-covered hot plate heated a "low heat."\* The procedure as previously described was then applied, and turbidimetric determinations made at the end of five and ten dryings. No increase in fixation was found to have taken place after the fifth drying, but the determinations showed an increase of from 200 to 400 per cent of the fixation at 70° C.

It was evident from this that such a treatment would give the maximum fixation possible, but under conditions of heating not existing in the fields. As with the single drying, no correlation was possible.

\* For this particular hot plate, it was found to be about 95° C. It was noted that the temperature of the heated soil remained at 70° C. until nearly dry, rising to 95° C. as the amount of evaporation decreased.

Attention was then diverted to stabilized heating through the use of water and sand baths. Tests run involved the use of a flat-bottomed pan placed on a hot plate and filled to the depth of one-half inch with sand. Uneven surface heating was evident, but the per cent fixation was in fair agreement with that of the constant temperature water bath.

The best correlation was found possible through the use of a water bath placed on a hot plate. The maximum temperature of the water in the bath at low heat was found to be slightly greater than desired, but the use of asbestos sheets under the pan was found to remedy the situation.

It was concluded that for plantation use, the necessary amount of insulating material to be used could only be determined on the premises, due to the differences in the heating capacities of the various hot plates in use. The temperature to which the bath\* is adjusted should be approximately 72° C., allowing a drop of 2° C. in the transmission of heat through the beakers. A wire basket suspended from the upper edge of the water bath and submerged to a depth of ¼ inch serves to keep the beakers off the bottom of the pan.

The optional method for the rapid determination of potash in soils as adapted for the determination of the degree of potash fixation in soils is here given.

#### THE RAPID DETERMINATION OF IRREPLACEABLE POTASH FIXATION IN SOILS

##### *Equipment Required:*

- 1 Tortion or platform balance, accurate to 0.001 gm.
- 1 Aluminum weighing dish with counterpoise, size 19.
- 2 Burettes, dispensing, 250-ml. capacity.
- 2 Covers for 250-ml. dispensing burettes.
- 24 Flasks, Erlenmeyer Pyrex, 125-ml. capacity.
- 24 Beakers, Pyrex glass, 50-ml.
- 12 Beakers, Pyrex glass, 250-ml.
- 12 Glass stirring rods, 5 inches long.
- 1 Water bath, constant level, 12" x 24".
- 1 Electric hot plate, 12" x 24".
- 4 Sheets of asbestos paper, cut to fit hot plate.
- 1 Thermometer, -10° C. to 110° C.
- 24 Funnels, glass, short stem, 65-mm. diameter.
- 4 Pkgs. Munktell No. 3, 11-cm. filter paper.
- 24 Vials, shell, short form.
- 1 Pipette, Mohr, 2-ml. calibrated to 0.01 ml.
- 1 Pipette, Mohr, 1-ml. calibrated to 0.01 ml.
- 1 Pipette, Exax volumetric, 5-ml.
- 2 Burettes, Exax, 50-ml.
- 2 Covers, for 50-ml. burettes.
- 1 Adapter for the burette containing Reagent No. 2 K<sub>2</sub>O.
- 2 Inclined vial block supports.
- 1 Potash rotator, electric.

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\* A constant level water bath may be obtained at a small cost.

- 2 Supports, iron, 6" x 9".
- 1 Clamp, burette, Lincoln.
- 1 3-foot section of 5-mm. rubber tubing for use with distilled water dispensing burette.
- 1 Pinchcock.
- 2 Clamps, castaloy, large, with rubber-covered jaws.
- 1 Funnel support, 10 holes.
- 1 Spatula, stainless steel, 4-inch blade.
- 1 Dropping bottle, amber, pipette stopper with knob at tip, 30-ml.
- 1 Gal. Reagent No. 1  $K_2O$ .
- $\frac{1}{4}$  Pint Reagent No. 2  $K_2O$ , in glass-stoppered bottle.
- 1 Pint Reagent No. 3  $K_2O$ .
- 1 Pint  $K_2O$  Fixation Solution No. 1.
- $\frac{1}{2}$  Pint  $K_2O$  Fixation Solution No. 2.
- 1 Gallon distilled water.

*Remarks:*

Although it is doubted that fixation will exceed 33 per cent of the amount of potash added, provisions are made for the determination of fixations up to 81 per cent. For this purpose, two potash fixation solutions are provided.

This procedure may be adapted to potash fixation studies under various fertilization practices.

*Procedure:*

1. Weigh 10.0 grams of the soil samples to be tested, placing in duplicate, one set in marked 250-ml. beakers, and the other set in marked 125-ml. flasks.

2. (a) To each flask containing 10.0 grams of soil add 28 ml. of Reagent No. 1,  $K_2O$ , pipette 2 ml. of Potash Fixation Solution No. 1 into each flask.

(b) Swirl for  $\frac{1}{2}$  minute. Filter through Munktell No. 3, 11-cm. filter paper into clean 50-ml. beakers.

(c) By means of a 1-ml. Mohr pipette, transfer two 0.5-ml. portions into each of two potash vials.

(d) Deliver 0.5 ml. of Reagent No. 1,  $K_2O$ , from a 50-ml. burette into each vial, making the total volume of the liquid in each up to 1 ml.

(e) Add four drops of Reagent No. 2,  $K_2O$ , to each of the vials and mix thoroughly.

(f) Immediately introduce 1 ml. of Reagent No. 3,  $K_2O$ , from a 50-ml. burette, provided with the special adapter at the tip, placing the vial on a block support with the tip of the adapter touching the inner wall of the vial. Turn the stopcock on full, and allow 1 ml. of the reagent to run onto the solution in the vial. Two distinct liquid layers should be visible. In case the layers are broken or a cloudiness appears between them, discontinue and repeat steps 2 (c) to 2 (f) until two distinct layers are obtained.

(g) Place the vials in opposite slots of the potash rotator and rotate for exactly 30 seconds.

(h) Transfer the vials to the potash illuminator and, 30 seconds after stopping the rotator, make the turbidimetric readings by moving the slide back and forth over the lined chart and sighting downward through the column of the test liquid.

(i) Should the reading be two or less, repeat steps 2 (c) to 2 (h) using successively larger (by 0.1 ml.) aliquots of the extract, until all readings of 2 and 3 are obtained. Do not record a high 2 reading as a 3 reading. Do not record high 1 readings, but be sure to record high 3 readings. Eliminate extremes which cannot be duplicated consistently.

(j) Should the reading be 3, record this as such. Pipette 5 ml. of the extract into a clean, dry 50-ml. beaker and dilute it with 5 ml. of Reagent No. 1,  $K_2O$ . Mix thoroughly and repeat step 2 (i) with this diluted extract.

(k) Should the reading obtained in 2 (j) be 3 or greater, place another 5-ml. aliquot of the extract in a clean, dry 50-ml. beaker and dilute this with 10 ml. of Reagent No. 1,  $K_2O$ . Mix thoroughly and repeat step 2 (i).

(l) Refer to the data sheet for the value of the turbidimetric readings in terms of R.C.M. potash.

*Note:* Turbidimetric Potash  $\times$  3.5 gives Replaceable Potash.

3. To the set of soils in the 250-ml. beakers add 8 ml. of distilled water. Pipette 2 ml. of Potash Fixation Solution No. 1 into each beaker. Place a stirring rod in each beaker. Stir the soil well, and allow the stirring rods to remain throughout the ten drying processes.

(a) Heat the water bath to the maximum of the "low" heat of the hot plate. By adjusting the thickness of the insulating material between the bath and the plate surface, the water should be heated to a temperature of  $72^{\circ}$  C. Check this with the thermometer.

(b) Place the beakers containing the soil suspension on the screen of the water bath. Check the temperature of the suspension occasionally. Allow the soils to dry for one hour, or until friable.

(c) From the 250-ml. dispensing burette equipped with a 3-foot section of rubber tubing and a pinchcock, add 10 ml. of distilled water to each beaker, without removing it from the bath. Stir thoroughly, wetting any soil which may adhere to the sides of the containers.

(d) Repeat alternate wettings and dryings for a total of ten dryings. Should it be necessary to halt the procedure before ten dryings have been completed, do so at the end of an evaporation period. Do not add water again until the bath has had time to re-heat to temperature.

(e) Add 30 ml. of Reagent 1,  $K_2O$  to the soil after the tenth drying. Extract and determine the replaced potash by steps 2 (b) to 2 (l) inclusive.

4. Pounds per acre fixed is equal to the potash as determined in part 2 minus that as determined in part 3, multiplied by the factor 3.5.

5. Per cent fixation is equal to pounds per acre fixed multiplied by 100, and divided by pounds per acre as determined in part 2.

Should the amount of fixation be greater than 33 per cent repeat the entire procedure, using Potash Fixation Solution No. 2; 1 ml. of this solution applied to 5 grams of soil is equivalent to an application of potash at the rate of 4,900 pounds



per acre-foot, and will necessitate considerable dilution in making determinations by part 2 of the above procedure.

To adapt this procedure as outlined, for potash fixation studies under various fertilizer practices, use in addition to the potash fixation solutions, standard fertilizer solutions as prescribed on the labels of their containers.

*Precautions:*

It must be noted that variations in the temperature of evaporation, inaccurate measurement of the potash fixation solution added, and the improper reading of the turbidities in step 2 (i) may introduce considerable errors.

REAGENTS USED\*

*Reagent No. 1,  $K_2O$ :*

An aqueous solution of sodium acetate, C.P., 500 grams in 8,000 ml. of distilled water. To 10,500 ml. of this solution are added 4,500 ml. of C.P. nitric acid in 1-1 solution.

*Reagent No. 2,  $K_2O$ :*

A solution of C.P. cobaltous nitrate, 318 grams and C.P. sodium nitrite, 1,200 grams in distilled water, 4,000 ml. containing 100 ml. of C.P. acetic acid. This reagent must remain for a time in storage in the dark, later is filtered, tested and shipped in small, amber glass-stoppered containers. It decomposes rather readily in the tropics and requires occasional inspection.

*Reagent No. 3,  $K_2O$ :*

Redistilled ethyl alcohol, exactly 95 per cent, containing the denaturants pyridine and xylol.

*Potash Fixation Solution No. 1:*

4.432 grams of C.P. potassium chloride dissolved in 1,000 ml. of distilled water.

*Potash Fixation Solution No. 2:*

15.530 grams of C.P. potassium chloride dissolved in 1,000 ml. of distilled water.

Additional fertilizer solutions used in the experimental work were:

*Calcium Hydroxide:*

Prepared as a 0.004 Normal solution by saturating 1,000 ml. of distilled, carbon dioxide free water with C.P. calcium oxide, and subsequently standardizing by titration. 16.1 ml. applied to 10 grams of soil are equivalent to an application of 6,000 pounds of the hydroxide per acre-foot.

*Mono-calcium Phosphate:*

Dissolve 1.775 grams of C.P. acid phosphate in distilled water and make up to 1,000 ml. 1 ml. applied to 10 grams of soil is equivalent to an application of 250 pounds of  $P_2O_5$  per acre-foot.

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\* Reagents No. 1, 2, 3,  $K_2O$  are described as given in *Soil and Plant Material Analyses by Rapid Chemical Methods*, The Hawaiian Planters' Record, 40, page 236, 1936.

The effect of non-potash fertilizers on fixation was determined by the following treatments:

*Treatment A:*

Potash applied as a solution of the chloride at the rate of 1,400 pounds per acre-foot of 2.5 million pounds weight, and immediately extracted and determined.

*Treatment B:*

Same as "A" except for artificial weathering prior to extraction and determination.

*Treatment C:*

Potash applied as in "A," and calcium as a solution of the hydroxide, at 6,000 pounds per acre-foot. The samples were weathered prior to extraction and analysis.

*Treatment D:*

Potash and lime were added as in "C." In addition, mono-calcium phosphate was added at the rate of 250 pounds per acre-foot.

TABLE II

PER CENT FIXATION OF POTASH APPLIED AT THE RATE OF 1,400 POUNDS PER ACRE-FOOT, AS INFLUENCED BY NON-POTASH FERTILIZERS

Soil	A	B	C	D
Kona .....	0.00	0.00	0.00	0.00
Olaa (uncultivated) .....	0.00	11.3	1.5	12.3
Olaa (cultivated) .....	0.00	4.7	6.4	3.9
Superior clay .....	0.00	43.8	52.0	49.7

It is obvious that material savings of potash may be realized by the proper control of potash fertilization of soils exhibiting a high degree of fixation of the nutrient.

SUMMARY

The phenomena of potash fixation in difficultly available forms in some soils are of uncertain mechanism.

Some Hawaiian soils exhibit a tendency to fix potash in irreplaceable forms.

Fixation is increased in some soils under some conditions of fertilization. It may be reduced by proper fertilization control, by frequent and small potash applications, and by sub-surface fertilization.

Potash fixation studies may be conducted on plantations by means of an adaptation of the rapid chemical method for the determination of potash in soils, as devised by the Experiment Station, H.S.P.A.

Satisfactory accuracy may be maintained by using weighed soil samples and the method of cross checking turbidimetric values of various aliquots on the data sheet.

No correlation could be found between different temperatures of weathering and the resulting degrees of fixation.

A study of the availability of the fixed potassium to such long crops as sugar cane can be conducted only in field tests.

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# Occurrence of the Minor Elements in Commercial Fertilizers as Determined Spectrographically

By STANLEY S. BALLARD

## INTRODUCTION

In reviewing the pages of popular and of scientific literature the farmer is bound to find discussion, from time to time, warning him of the dangers of artificial fertilization where highly refined synthetic chemical compounds have been used as a substitute for the old standard natural products originating in stable refuse or in other animal, mineral or vegetable sources.

There can be no question as to the justification of this warning, for numerous studies have been described in the literature by workers in this field in which it has been shown that cropping in soils deficient in certain minor nutrients may not be restored to maximum or even to moderate yield by application only of relatively pure nitrogen, phosphoric acid and potash.

The so-called "less essential" elements play a very important role in plant nutrition. It is equally true that the more common elements function similarly, but they are necessary to the plants in much larger amounts. It is not an unusual practice to spray growing plants on a very large scale with a dilute solution of ferrous sulphate as a corrective for iron deficiency in those plants. Yet, the soil supporting the plants may consist largely of various forms of hydrated but difficultly soluble ferric oxide.

Therefore, solubility of required plant nutrient is an important factor. It is perhaps immaterial whether the nutrient remains soluble *after* application to the soil or whether it becomes soluble from an insoluble source by the action of the soil solution or of plant root systems. For instance, plant responses to exceedingly small applications to the soil of insoluble compounds of zinc, manganese and copper have been reported, while soluble sources of these same less common nutrients have been found equally effective. The difficultly soluble raw rock phosphate appears to be made available to plant life in either an acid or an alkaline soil medium.

Most fertilizer compounds in use today, whether synthetic or natural, are readily soluble. Many of them are endowed with a great variety of the minor elements. It should be of interest, therefore, to become acquainted with the extent and abundance of this nutrient endowment in present-day fertilizers as shown by Dr. Ballard in his brief but excellent summation of an extended program of spectrographic research on this subject.

FRANCIS E. HANCE.

## DISCUSSION

It has been well known for some years that the ten most important elements to plant growth are carbon, hydrogen, oxygen, sulfur, nitrogen, phosphorus, potassium, calcium, magnesium, and iron. These elements are all essential to normal growth and must be available to the plant in fairly large amounts. Only the last six are ordinarily involved in fertilizer considerations. In recent years it has been shown

that in addition to the ten major elements there are certain other elements that are equally essential to normal growth, but are necessary in only small amounts. These are the so-called micro-metabolic, minor, less common, or "less essential" elements. Included in this group, for most plants, are manganese, boron, copper, zinc and perhaps aluminum and iodine. Then there are certain others whose importance to plants is at present being investigated, such as cobalt, nickel, tin, silicon and sodium. Certain other elements such as strontium and barium are often found to be present in plants, but are not known to perform any function therein.

Chemical fertilizer analyses, using either the standard or rapid chemical methods, may readily be made for the last six of the major elements listed above, and the spectrograph cannot compete here. The case of the minor elements is quite different, however. These elements are needed in such small amounts—only a few parts per million in the soil will often suffice—that their chemical determination is exceedingly laborious. They are ordinarily present in only small amounts in fertilizers also, and it is here that the sensitive and rapid semi-quantitative spectrographic method finds good application.

In this article there is reported the analysis of twelve commercial fertilizers commonly used in the Hawaiian sugar industry. The purpose was to secure a complete qualitative (or better, semi-quantitative) analysis of the materials for their mineral composition. Such an analysis reveals the presence or absence of about one-half of the ninety-two chemical elements, this list including all the metals and some of the metalloids. It therefore includes all the major and minor plant nutrients mentioned above except carbon, hydrogen, oxygen, nitrogen, sulfur and iodine. Of particular interest are the results for the minor elements. It is interesting also to note that certain fertilizers contain traces or small amounts of certain major elements other than the major nutrient constituent of the fertilizer. Also, since in the future other minor elements may be found to be essential to plant growth, it should be worth while to have on record the results of the *complete* analysis of the mineral composition of typical fertilizer materials.

Samples of the twelve commercial fertilizers were obtained from The Pacific Guano and Fertilizer Company of Honolulu. These are listed in Table I.

TABLE I

NAMES AND SOURCES OF THE TWELVE FERTILIZERS  
ANALYZED SPECTROGRAPHICALLY

Name	Source
Sulfate of ammonia	Trail, B. C. (Canada)
Sulfate of ammonia	Eastern U. S.; a by-product
Nitrate of soda	Hopewell, Va.
Nitrate of soda *	Chile
Potash nitrate	Chile
Potash nitrate	Germany
Muriate of potash	Mojave Desert, California
Raw rock phosphate	Makatea (South Pacific)
Superphosphate	Made from Makatea rock
Raw rock phosphate	Florida
Superphosphate	Made from Florida rock
Ammo-Phos	American Cyanamid, Warners, N. J.

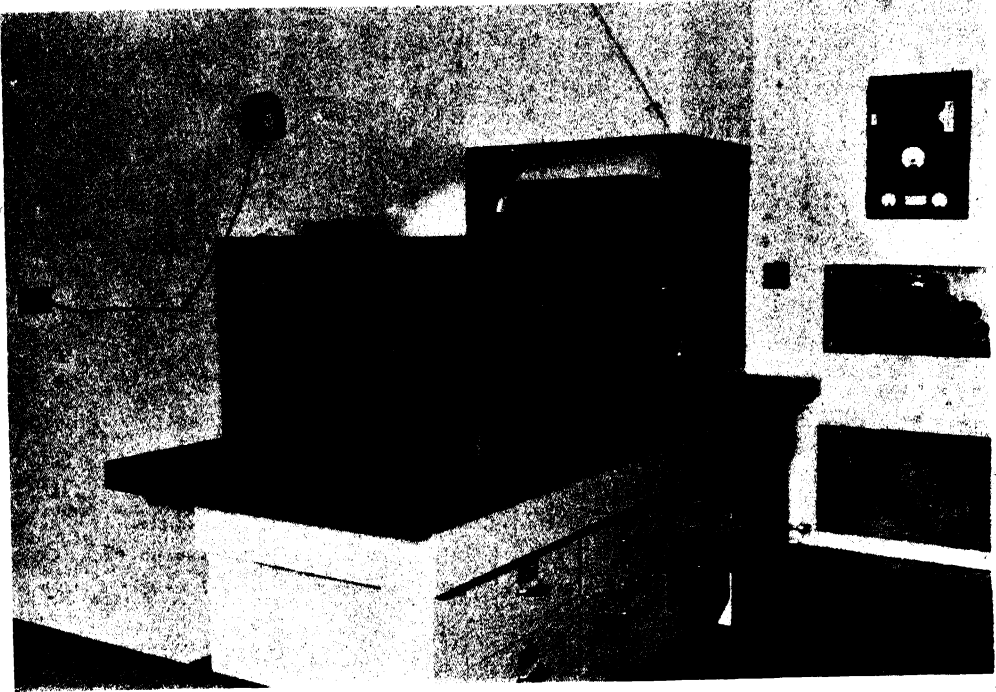


Fig. 1. The large quartz spectrograph. Note the hood over the far (plate-holder) end and the electrical control panel.

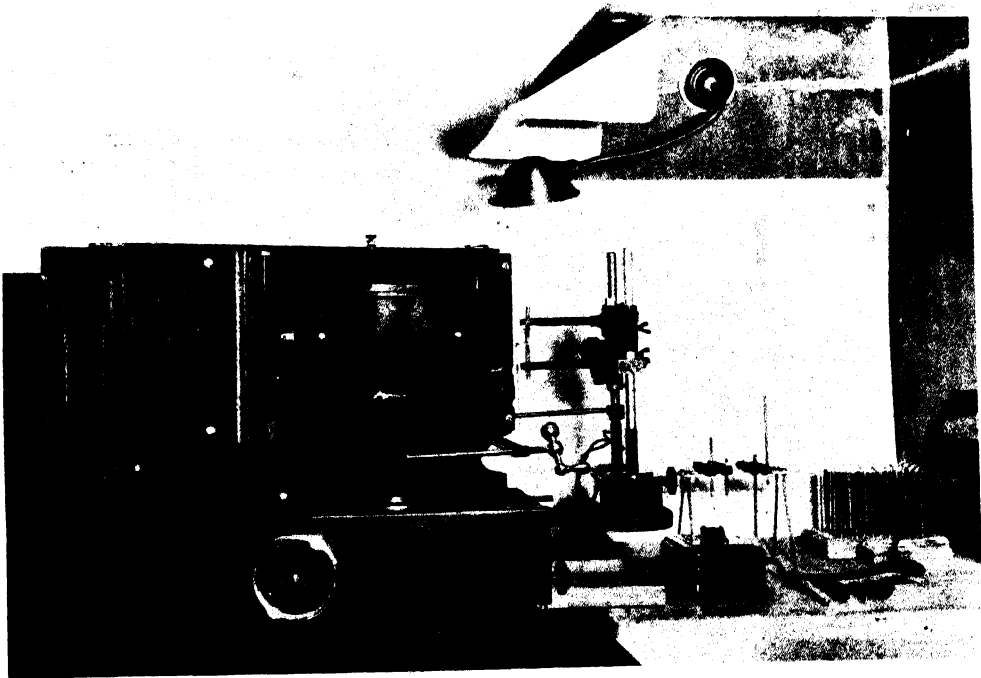


Fig. 2. Plate-holder end of spectrograph. The hood draws off fumes from the arc. Note the carbon arc, the rack with copper and iron electrodes, the prepared carbon electrodes (protected by inverted test tubes) and the reversing switch in the arc electrical supply line.

The technic used in obtaining the spectrograms was to incinerate weighed portions of the samples in copper and in carbon arcs and to photograph the light from the arc with the large quartz Littrow spectrograph shown in Figs. 1 and 2. The glowing arc stream is composed of atoms and ions of the constituents of the sample, as well as those of the electrode material. The spectrum of the light from the glowing arc therefore showed lines due to the various elemental constituents of the sample. Since the constituents of the electrodes were also registered, the purity of the electrode material was a matter of paramount importance. We used graphite and copper electrodes of the highest purity obtainable. The preparation of the electrodes was conducted with great care so that no impurities were introduced. A new method of introducing the samples into the arc which should avoid all contamination of the sample was devised and used. In all cases the spectrum of the bare electrodes was first photographed on the spectrum plate, this step being necessary in order to determine what impurities were present in the arc electrode material. In general the carbon electrodes were the freest from impurity, showing traces only of boron and silicon, while the copper electrodes showed impurities of tin, lead, nickel and iron. Arcing times of one minute sufficed for the complete incineration of the sample. The carbon arc current was maintained at 6.5 amperes and the copper arc current at 5 amperes. Voltage drops across the arc were 60-55 volts for the carbon arc and 40 volts for the copper arc.

For each fertilizer two plates were taken, one in our Range I which includes the visible part of the spectrum and one in Range II which lies entirely in the ultra violet. Thus this project involved taking twenty-four plates, two for each of the twelve samples. On each plate were photographed seven spectrum strips, one strip being the spectrum of the bare carbon electrodes, one of the carbon electrodes with a weighed portion of 10 mg. of the sample burning, one of the same electrodes with a large amount of sample, say 40-50 mg. burning, three copper exposures which were similar to the carbon exposures and a strip of iron spectrum. Lines in the rich spectrum of iron are always used as wave length comparison standards. The constitution of the various fertilizer samples could be compared in a quasi-quantitative fashion by referring to the spectrum strips of the equal weighed portions of 10 mg., while the spectra of the larger portions showed lines of the elements present in the smallest amounts. It might be mentioned that the arc currents used in this investigation, as well as the constant arc length of 4 mm., did not represent extreme exposure conditions. Fig. 3 is a reproduction of the Range I plate of Chile potash nitrate.

Since such small amounts of material were used in each analysis the method of sampling was of great importance. In order to obtain the small samples we first spread out the entire contents of the two-pound bottle on a piece of heavy paper and mixed it thoroughly. The material was then quartered repeatedly, small portions being drawn out until about 10 grams had been removed. The 10 grams of material were ground fine in a carefully cleaned agate mortar and were dried in a dust-proof electric oven. The 10- to 50-mg. samples of the pulverized fertilizer were then taken from this portion. We felt that these small samples represented as accurately as possible the material as we received it. We had no control, of course, over the original sampling of the fertilizers as they were received in Honolulu.

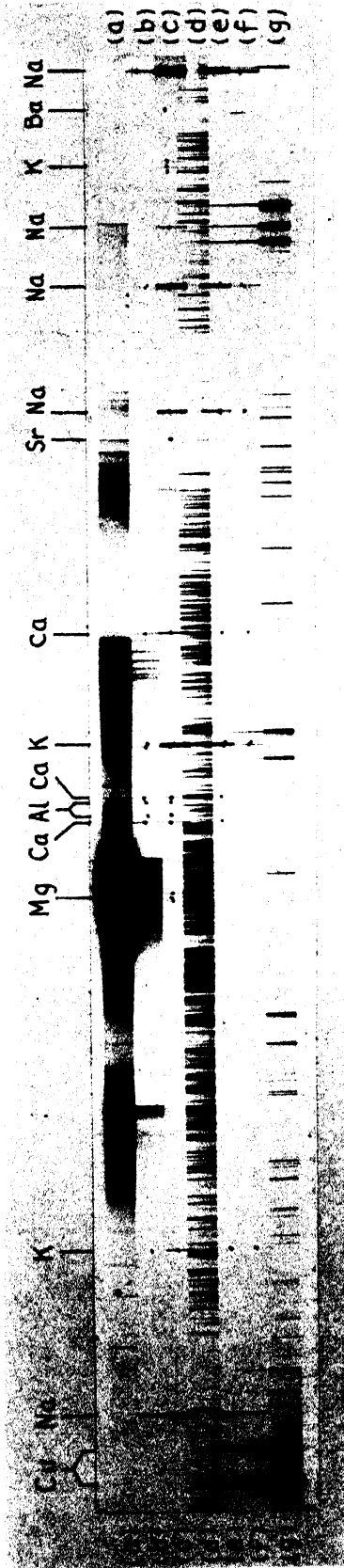


Fig. 3. Range I spectrogram of Chile potash nitrate fertilizer. Lines due to elements in the sample are dotted and their designations indicated. The seven strips are due to the following are situations: (a) bare carbon electrodes; (b) carbon electrodes with 10 mg. of sample incinerated; (c) carbon electrodes with 40-50 mg. of sample incinerated; (d) iron electrodes, to give wavelength standards; (e) copper electrodes with 40-50 mg. of sample incinerated; (f) copper electrodes with 10 mg. of sample incinerated; (g) bare copper electrodes. The strips are photographed in the order (a), (b), (c), (d), (e), (f), (g). Note that the copper lines show in the last four strips but not in (a), (b) or (c). This shows that copper is an impurity of the iron electrodes, but does not occur in the carbon electrodes or in the sample. The heavily blackened areas in strips (a) and (b) are the cyanogen bands that are always produced by a carbon are run in the air.

The Range II plate of Chile potash nitrate (not reproduced) shows that the sample contains iron as well as potassium, calcium, magnesium, aluminum, sodium, strontium and barium.



The collected results of the analyses of the twenty-four spectrum plates are given in Table III. Although this was essentially a qualitative method, some attempt was made to give semi-quantitative results. Thus, if the number and intensity of spectrum lines occurring on the plate indicated that the element concerned was present in a large amount in the sample, being perhaps a major constituent, we applied the designation "lots"; if the element was present in fairly large amounts, but was probably not a major constituent, we used the designation "some"; if the element appeared to be present in even smaller amounts, but still more than trace amounts, we used the designation "less"; if only the most sensitive lines of the element appeared on the spectrum plate a "trace" was reported. In order to give an even closer comparison between similar samples the added designations "plus" and "minus" were sometimes used, but such fine distinctions may not be significant in an analysis of this type. If the element was looked for, but not detected, it was specified as "N.D." in the table. If no designation was given, the element was not definitely looked for in the sample, probably because all the lines appearing on the spectrum plate had already been accounted for. These semi-quantitative designations are repeated in Table II.

TABLE II  
SEMI-QUANTITATIVE DESIGNATIONS, ARRANGED IN THE ORDER OF  
DECREASING QUANTITY OF THE ELEMENT PRESENT IN THE SAMPLE

Lots  
Some  
Less  
Trace  
N. D. (not detected)

It should be stated that if an element was not detected it might still have been present in the sample, but in such very small quantities as to escape detection; in fact in certain borderline cases it was difficult to state whether a "trace" of the element was present or not. Minor fluctuations in the electrical conditions of the arc might be sufficient either to make the sensitive lines of the element barely visible or to subdue them in such cases. This effect was probably encountered in the case of boron, as discussed below.

TABLE III  
COLLECTED RESULTS OF THE SPECTROGRAPHIC ANALYSIS OF TWELVE COMMERCIAL FERTILIZERS

Chemical element and symbol	Sulfate of ammonia (Canada)	Sulfate of ammonia (U. S.)	Nitrate of soda (Va.)	Nitrate of soda (Chile)	Potash nitrate (Chile)	Potash nitrate (Germany)	Muriate of potash (Calif.)	Raw rock phosphate (Makatea)	Super- phosphate (Makatea)	Raw rock phosphate (Florida)	Super- phosphate (Florida)	Ammo-Phos (N. J.)	Chemical element
Phosphorus, P	Trace	N.D.		Trace	Lots	Lots	Lots	Lots	Lots	Lots	Lots	Lots	Phosphorus
Potassium, K			N.D.		Lots	Lots	Lots	N.D.	N.D.	N.D.	N.D.	N.D.	Potassium
Calcium, Ca	Trace	Trace	Less—	Less	Less+	Some	Trace	Lots	Lots	Lots	Lots	Some—	Calcium
Magnesium, Mg	Trace	Trace	Trace	Less	Less	Less	Trace	Less+	Less	Less	Less	Less+	Magnesium
Iron, Fe	Less—	Less	N.D.	N.D.	Trace	Trace	N.D.	Some	Some	Some	Some	Some	Iron
Manganese, Mn								Less+	Less—	Less	Less	Some—	Manganese
Boron, B*								N.D.	N.D.	N.D.	N.D.	Trace	Boron*
Copper, Cu	N.D.	Trace	N.D.	N.D.		N.D.	Trace	N.D.	Trace	Trace+	Trace—	Trace+	Copper
Zinc, Zn	N.D.	Trace						Trace	Trace	Trace	N.D.	N.D.	Zinc
Aluminum, Al	N.D.	Trace+	N.D.	Trace	Trace+	Trace+	N.D.	Some	Less	Less	Less+	Some	Aluminum
Nickel, Ni								N.D.	N.D.	Trace	Trace	Trace—	Nickel
Silicon, Si	Trace	Trace						N.D.	N.D.	Less	Less	Some	Silicon
Sodium, Na		Trace	Lots	Lots	Lots—	Less	Some—	Less	Less	Less	Less—	Less+	Sodium
Titanium, Ti								Trace	Trace	Trace	Trace	Trace—	Titanium
Lead, Pb	Trace	Trace						Trace	Trace	Trace	Trace	Trace	Lead
Chromium, Cr								Less	Less	Trace+	Trace+	Trace	Chromium
Strontium, Sr			N.D.	N.D.	Trace	Trace	N.D.	Trace+	Trace+	Trace+	Trace+	Trace	Strontium
Barium, Ba			N.D.	N.D.	Trace	N.D.	N.D.	N.D.	N.D.	Trace—	Trace—	N.D.	Barium
Vanadium, V								N.D.	N.D.	Trace	N.D.	Trace	Vanadium
Molybdenum, Mo								N.D.	N.D.	N.D.	N.D.	Trace	Molybdenum
Fluorine, F								Less+	Less+	Less	Less	N.D.	Fluorine

\* See discussion in text regarding low sensitivity of boron detection.

There is also the factor that the various elements differ considerably in their arc sensitivity. For instance, sodium detection by a certain spectrographic technic may be a thousand times more sensitive than phosphorus detection. For this reason it is important to know the relative arc sensitivity of the various elements commonly encountered in agricultural work. In Table IV are given the approximate lower limits of detection of the elements encountered in this investigation. The absolute amounts quoted apply only to the technic used and are at best only very approximate.\*

TABLE IV

TABLE SHOWING APPROXIMATE SMALLEST AMOUNTS OF THE VARIOUS ELEMENTS DETECTABLE SPECTROGRAPHICALLY

Per cent	Parts per million	Elements
.0001 - .001	1 - 10	Magnesium, copper, nickel, sodium, chromium
.001 - .01	10 - 100	Calcium, iron, manganese, aluminum, titanium, lead, strontium, barium, vanadium, molybdenum
.01 - .1	100 - 1000	Boron, zinc, silicon
.1 - 1.0	1000 - 10,000	Phosphorus, potassium

The apparent insensitivity of potassium to spectrographic determination, with a lower limit of around one-tenth of one per cent, is due to the fact that the most sensitive lines of potassium lie at the far red limit of the visible spectrum, outside our standard ranges. We propose to establish a standard range in the far red so that small concentrations—say 10 parts per million—of potassium can be detected. Other elements whose sensitive lines lie in this region are lithium, rubidium and cesium. Boron, zinc and silicon are also relatively insensitive, only 0.01 to 0.1 per cent being detectable spectrographically by the technic used in the present investigation. However, we now have available a stronger, more searching technic which involves the use of higher arc currents and shorter arc lengths and which increases the sensitivity of boron and zinc detection, as well as that of the other arc-sensitive elements, perhaps a hundredfold. The sensitive lines of arsenic and beryllium lie even deeper in the ultra violet than our Range II, so that these two elements could not be analyzed for in the present investigation. Since this work was done, however, we have established a special range which includes the sensitive lines of arsenic and beryllium and in which we can reach a lower limit of about 20 parts per million in arsenic detection in soils.

Due to the important effect upon the behavior of the arc of the identity of the major constituents of a sample, comparisons of relative amounts of impurities in samples of different major composition must be made with extreme caution. For this reason the various fertilizers listed in Table III will be discussed in groups, each group being arranged so that all its members will have approximately similar major constitution and will hence be readily comparable.

\* These data are adapted from the work of Ryde and Jenkins of the General Electric Co. Research Laboratories (England). *Wavelength Tables for Spectrum Analysis*, p. 130, 2nd Ed. 1931, Adam Hilger, Ltd., London.

TABLE V  
AMMONIUM SULFATE FERTILIZERS

Chemical element and symbol	Sulfate of ammonia (Canada)	Sulfate of ammonia (U. S.)
Phosphorus, P .....	Trace	N.D.
Calcium, Ca .....	Trace	Trace
Magnesium, Mg .....	Trace	Trace
Iron, Fe .....	Less—	Less
Copper, Cu .....	N.D.	Trace
Zinc, Zn .....	N.D.	Trace
Aluminum, Al .....	N.D.	Trace+
Silicon, Si .....	Trace	Trace
Sodium, Na .....	Trace	Trace
Lead, Pb .....	Trace	Trace

Table V gives the results of the analysis of two fertilizers whose major constituent was ammonium sulfate. In the case of these two samples, *every* unknown line on the spectrum plates was accounted for and so a complete analysis of the fertilizers for the fifty-odd arc-sensitive elements was made. An inspection of the table reveals that the U. S. sulfate of ammonia sample contained more iron than the Canadian sample and contained traces of copper, zinc and aluminum. The Canadian sample, on the other hand, contained a trace of phosphorus. In general it is seen that the ammonium sulfate fertilizers contained relatively few impurities and that all of these occurred in very small amounts.

TABLE VI  
FERTILIZERS CONTAINING A LARGE AMOUNT OF AN ALKALI METAL  
(SODIUM OR POTASSIUM)

Chemical element and symbol	Nitrate of soda (Va.)	Nitrate of soda (Chile)	Potash nitrate (Chile)	Potash nitrate (Germany)	Muriate of potash (Calif.)
Potassium, K .....	N.D.	Trace*	Lots	Lots	Lots
Calcium, Ca .....	Less—	Less	Less+	Some	Trace
Magnesium, Mg .....	Trace	Less	Less	Less	Trace
Iron, Fe .....	N.D.	N.D.	Trace	Trace	N.D.
Copper, Cu .....	N.D.	N.D.	N.D.	N.D.	Trace
Aluminum, Al .....	N.D.	Trace	Trace+	Trace+	N.D.
Sodium, Na .....	Lots	Lots	Lots—	Less	Some—
Strontium, Sr .....	N.D.	N.D.	Trace	Trace	N.D.
Barium, Ba .....	N.D.	N.D.	Trace	N.D.	N.D.

\* See discussion in text regarding low sensitivity of potassium detection.

In Table VI are repeated the analytical results for the five fertilizers that contained a large amount of an alkali metal (either sodium or potassium). It is well known that a large amount of an alkali metal dominates arc conditions to such an extent that the weak lines of "trace" elements are depressed in intensity or may actually be subdued entirely. For this reason it should be stated that the rather high purity of these samples is doubtless more apparent than real. Again, all the lines on the ten spectrum plates were accounted for.

TABLE VII

FERTILIZERS CONTAINING A LARGE AMOUNT OF AN ALKALINE EARTH  
(CALCIUM)

Chemical element and symbol	Raw rock phosphate (Makatea)	Super- phosphate (Makatea)	Raw rock phosphate (Florida)	Super- phosphate (Florida)	Ammo- Phos (N. J.)
Phosphorus, P .....	Lots	Lots	Lots	Lots	Lots
Potassium, K .....	N.D.	N.D.	N.D.	N.D.	N.D.
Calcium, Ca .....	Lots	Lots	Lots	Lots	Some—
Magnesium, Mg .....	Less+	Less	Less	Less	Less+
Iron, Fe .....	Some	Some	Some	Some	Some
Manganese, Mn .....	Less+	Less—	Less	Less	Some—
Boron, B .....	N.D.	N.D.	N.D.	N.D.	Trace
Copper, Cu .....	N.D.	Trace	Trace+	Trace—	Trace+
Zinc, Zn .....	Trace	Trace	Trace	N.D.	N.D.
Aluminum, Al .....	Some	Less	Less	Less+	Some
Nickel, Ni .....	N.D.	N.D.	Trace	Trace	Trace—
Silicon, Si .....	N.D.	N.D.	Less	Less	Some
Sodium, Na .....	Less	Less	Less	Less—	Less+
Titanium, Ti .....	Trace	Trace	Trace	Trace	Trace—
Lead, Pb .....	Trace	Trace	Trace	Trace	Trace
Chromium, Cr .....	Less	Less	Trace+	Trace+	Trace
Strontium, Sr .....	Trace+	Trace+	Trace+	Trace+	Trace
Barium, Ba .....	N.D.	N.D.	Trace—	Trace—	N.D.
Vanadium, V .....	N.D.	N.D.	Trace	N.D.	Trace
Molybdenum, Mo .....	N.D.	N.D.	N.D.	N.D.	Trace
Fluorine, F .....	Less+	Less+	Less	Less	N.D.

In Table VII are repeated the results of the analysis of the four fertilizers whose major constituent was calcium phosphate. Here the dominating element in the arc was doubtless calcium, and since the Ammo-Phos sample was found to contain a rather large amount of calcium the results of its analysis are included in this table. It should be stated, however, that a close comparison of Ammo-Phos with the other four samples would not be as reliable as comparisons between these four. In the case of these five samples the spectra were very complicated, due to the large number of elements present and particularly to the considerable amount of iron, with its many-lined spectrum. For this reason, rather than accounting for each one of the hundreds of lines occurring on each of the ten spectrum plates, each plate was examined for the presence or absence of all elements whose presence one had any reason to suspect. In addition to the twenty-one elements reported in Table VII and in Table III, the following were looked for but not detected in each of these samples: Cobalt, tin, silver, cadmium, bismuth, antimony, thallium, zirconium and germanium. Lithium, rubidium, cesium and beryllium were also looked for and not detected, but, as discussed above, their most sensitive lines lie outside the range covered by the spectrum plates. In some cases, namely Chile potash nitrate, muriate of potash, Canadian sulfate of ammonia and the Florida rock samples, "trace" lines of boron seemed almost to be indicated, but boron could not be reported with certainty. Repeating the plates with the new stronger technic mentioned above would readily show boron lines, if indeed boron was present in appreciable amount. This has not been done since boron does not appear to be a problem in Hawaiian agriculture at present.

Table VII shows that the last five fertilizers are the best sources of the minor elements. The comparison between the Makatea and Florida samples shows that the Makatea rock and superphosphate seem to have more chromium and fluorine while the Florida samples show traces of nickel, silicon and barium. The fact that copper showed as a "trace" in Makatea superphosphate while it was not detected in Makatea raw rock phosphate should not be given too much significance in view of the borderline nature of the "trace" designation discussed above. This also applies to zinc and vanadium in the Florida samples. In general, the metallic constitution of the rock phosphate and superphosphate fertilizers would seem to be as follows: "lots" of phosphorus and calcium, "some" iron, "less" magnesium, manganese, aluminum, sodium and possibly chromium and fluorine, and "traces" of copper, zinc, titanium, lead and strontium.

Thanks are due Paul E. Chu, Assistant Chemist, for his most valuable assistance in preparing the samples and in securing the twenty-four spectrograms. Grateful acknowledgment is made to R. Q. Smith of The Pacific Guano & Fertilizer Company for his helpful criticism of the manuscript.

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## Selenium—I

*A general discussion based upon the properties of the element, its absorption by plants and its effects upon horses, cattle and hogs as transmitted through forage*

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By FRANCIS E. HANCE

The element selenium occurs in the surface crust of the world in amounts calculated to equal that of silver. It has been found in meteors. Byers, Williams and Lakin (1) have published a discussion, with data, on its occurrence in Hawaii.

Interest in the natural presence of the element in farm and ranch lands is concerned principally with its purported property of adversely affecting grazing and other stock which are fed vegetation grown on seleniferous soils.

Selenium appears to be one of nature's outstanding elemental substances in the latitude of its properties, in the multiplicity of its uses and in the abnormal and frequently serious effects it may produce in certain animals when it enters their systems in food.

Selenium is indispensable to the rubber, electrical and glass industries. It is remarkably sensitive to light, so much so that by its employment light may be converted into electrical energy. When used with a suitable relay, a selenium light-sensitive cell may start and stop motors, ring or silence bells, light or extinguish lamps, protect safes, fire a cannon at a distance or function in many other operations, directly or by remote control. Selenium imparts to rubber a property which makes it resistant to abrasion, high temperature or even combustion. Hence, it is valuable and is used in automobile tire casings and inner tubes. Selenium rubber is used in insulating electrical cables which must withstand heat and continual movement over hard, rough surfaces. Selenium imparts a terra cotta red to rubber and a brilliant permanent scarlet to glass, enamelware and pottery. Diethyl selenide has been used as a satisfactory substitute for lead tetraethyl in anti-knock motor fuel. Colloidal selenium has the properties of a germicide, insecticide and fungicide.

One of its compounds, selenium oxychloride, approaches to a remarkable extent many of the desirable characteristics of the "universal" solvent long sought by ancient and, in a lesser degree, modern chemists.

The research chemist devoting his time in the laboratory to the study of selenium is a man apart from his fellows. His breath, perspiration and body carry odors of the foulest nature. This odor has been described as suggesting horseradish, garlic and brass, all combined. Commenting on selenium odors in man, a writer (5) in a publication by Arthur D. Little makes this statement: "The skunk might have a research job done by the chemist, using selenium, to *increase* his 'Schrecklichkeit' " (*frightfulness*).

In cereals, grasses and other vegetation, selenium may or may not give warning of its presence by imparting garlic-like odors. Such vegetation may prove swiftly or lingeringly fatal to animals which eat it. Frequent references are made in the literature to articles describing diseases and suffering in animals poisoned by eating forage contaminated with selenium.



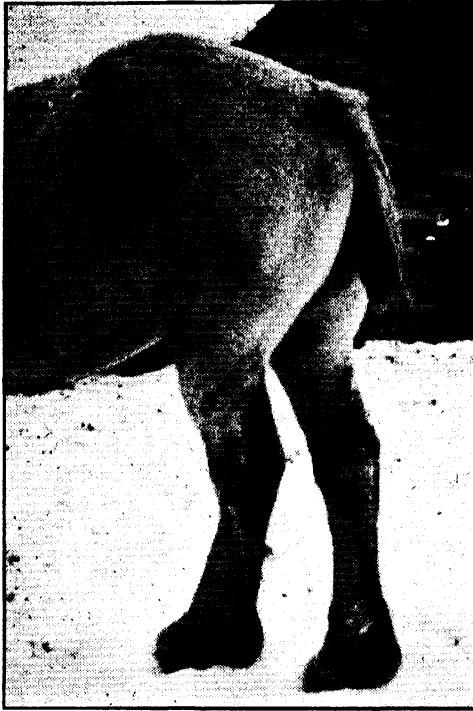


Fig. 1. This photograph shows the loss of the long hair from the tail after the horse had been on an affected ranch for only six weeks.



Fig 2. Cross section of a hoof from an "alkalied" horse. The arrows indicate points at which growth has been interrupted.

The toxicity to humans of food containing selenium does not appear to have been established, although Thorp (12), from soil studies made in China, expressed the belief that the symptoms of osteomalacia (softening of and deformities in bones) in humans may be due to selenium rather than to a deficiency of calcium or phosphorus in the soils.

Hurd-Karrer (3) states that it is not known whether man is susceptible to ills attendant upon a diet containing selenium. She adds that probably the danger is slight, particularly so in non-affected areas, because the normal human diet is so diverse.

In a field study made during 1936 upon a selected group of 50 rural families in a highly seleniferous soil area in four counties of South Dakota and Nebraska, Smith and Westfall (11) examined 100 urine specimens from 100 individuals and also the locally produced foodstuffs which constituted the principal diet of these people. They found that other than a high incidence of symptoms suggesting impaired functioning of the intestinal tract and a few cases of apparent hepatic dysfunction, no other evidence of ill health was seen that could be ascribed to selenium with any degree of certainty. The disorders found were believed due *probably* to continual selenium ingestion.

Commenting on the urine analysis field study made upon the South Dakota and Nebraska families discussed above, a writer (9) in the Pacific Rural Press makes this observation: "... human beings use as much as needed of such things as lead, arsenic, fluorine and selenium, establishing a useful balance, and excreting the remainder." This statement apparently is an opinion for no data are cited. It has been shown by Moxon and others that the organs of elimination and excretion, certainly in animals, are damaged by the poisonous effects of ingested selenium.

There appears to exist a very low level requirement in humans for many of the rare and even *poisonous elements*. A statement in a text by Mellor (6) credits T. Gassmann with finding selenium a constant constituent of teeth and bones. Gassmann stated that healthy teeth contain about 0.056 per cent of selenium (560 parts per million) and even in cases of diseased conditions of the teeth the same general figure prevails. Urine, he states, contains 0.0011 per cent of selenium in male and 0.0009 per cent in female persons. Vegetables also contain selenium, especially spinach. On the other hand, Mellor refers to another article by R. Fritsch in which the latter denies the presence of selenium in urine or in bones.

The finding by Gassmann regarding selenium in teeth does not appear to be questioned. To check on this point, however, the author and associate obtained several hundred specimens of extracted teeth from Honolulu dentists. In a thorough analytical study by E. K. Hamamura in this laboratory these teeth were found to be absolutely devoid of any suggestion or trace of selenium.

Colloidal selenium was found to give encouraging results in an investigation by Flury (2) in the treatment of hydrocyanic acid poisoning.

The human organism may or may not have a tolerant reaction to selenium occurring in foods. Data published on this point are not sufficient to justify either conclusion, for or against its toxicity to humans.

In a like manner the presence of the element selenium in soil does not appear to seriously retard the normal growth of many plants and grasses. In fact, it seems

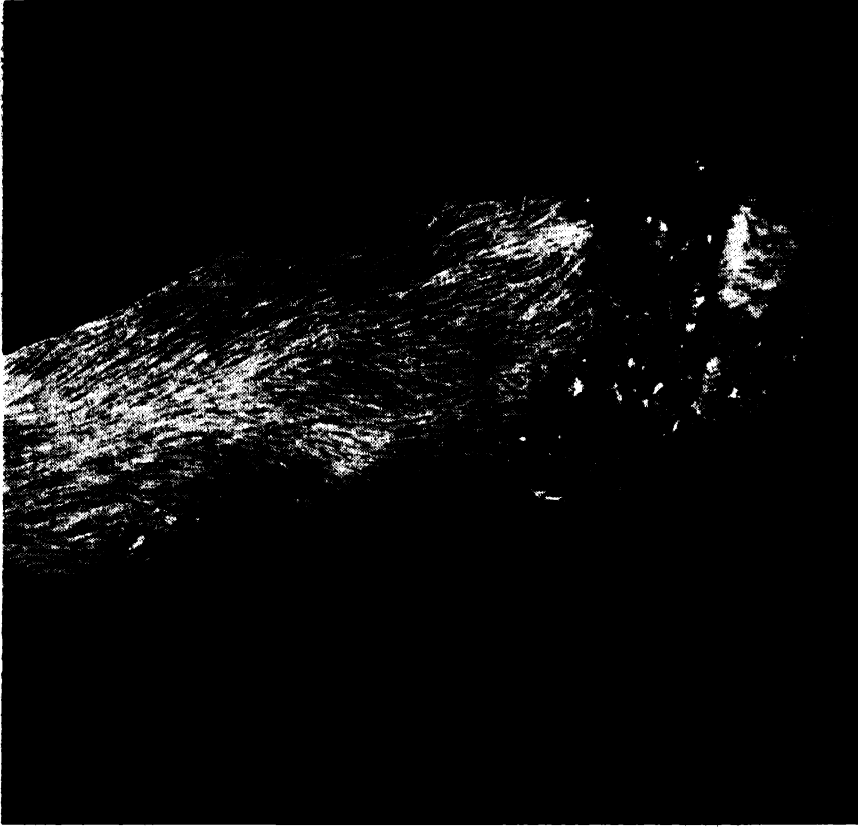


Fig. 4. Photograph showing the separation of the hoof from the foot of a 14-day-old colt. The colt was born with its feet in this condition.

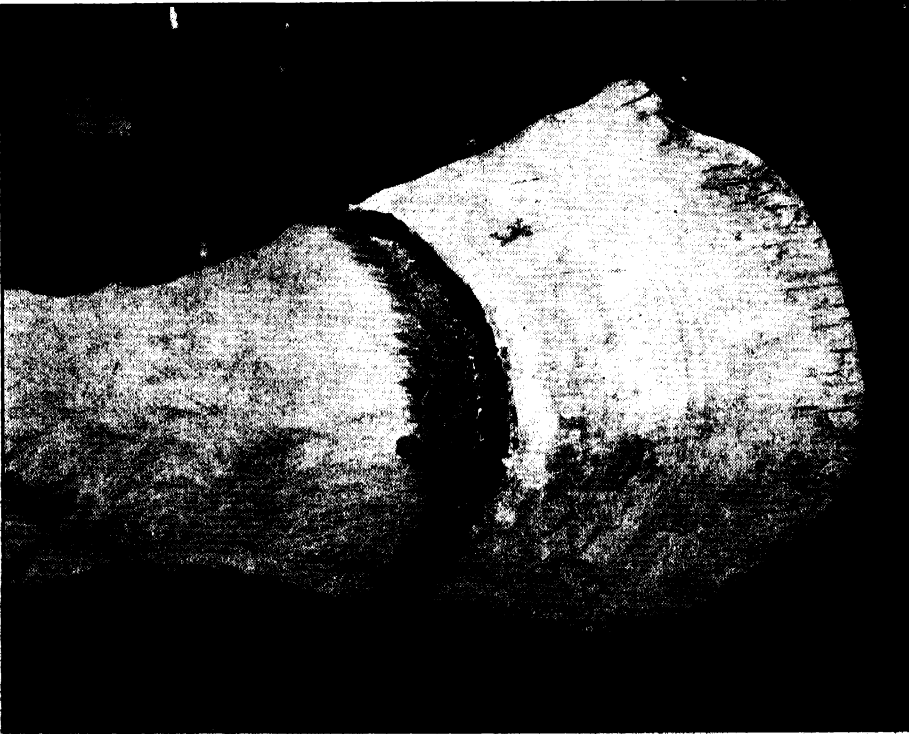


Fig. 3. This photograph shows the separation of the hoof from the foot of a horse which died after it had been on an affected ranch for only eight weeks.

that certain plants thrive on seleniferous soils and, moreover, the appearance of these plants in any given district may *indicate* the occurrence of selenium in the soil supporting them. Miller and Byers (7) have classified plants according to their tolerance for selenium in soil. Dividing such plants into 3 groups, they place in Group No. 1 plants that absorb selenium readily and which may be classed as the "indicator" type mentioned above. In Group No. 2 they place wheat, barley, rye and corn because of the fact that these cereals are able to absorb moderate or even large quantities of selenium without thereby suffering injury themselves. A third grouping is reserved for buffalo and grama grasses which, they state, have a very limited tolerance for selenium and are able to absorb only small quantities when grown on seleniferous soils.

Moxon (8) describes another class, which he terms "converter" plants. This class, typified by *Astragalus bisulcatus* and *A. pectinatus*, has the apparent ability of absorbing insoluble selenium from the soil and converting it into a semi-organic soluble form in the plant tissues. After maturing, dying and falling back on the soil, the decayed plant will leave its soluble selenium in a form which is available to wheat and other crop plants. He quotes similar observations by other investigators which support this premise.

Knight and Beath (4) report that seleniferous Wyoming shale, originally non-toxic, was converted to a toxic condition in three years by growing from seed some of the native seleniferous weeds *in situ*.

It is evident, therefore, that plant selectivity exists for selenium in soil. Also, that specific kinds of plants will absorb selenium from insoluble inorganic sources in the soil and in some cases actually build up or concentrate this absorbed selenium in a soluble, semi-organic form. Other plants growing in the same locality may ignore or reject the insoluble fraction of soil selenium. However, when the "converter" plants return their soluble selenium to the soil in an available form, then *any* growing vegetation may take it up and perpetuate the cycle of selenium conversion.

These facts established, a discussion will be presented on the observed effects of selenium, when present in forage vegetation and grain, upon mainland animals and poultry which consume it in food. It is this phase of the subject which commands our principal interest in Hawaii, for symptoms of selenium poisoning in animals have been observed here and the presence of the element in Hawaiian soils has been reported by Beyers et al (1) and found by ourselves.

As pointed out by Moxon (8), the first recorded reference, perhaps, to alkali (selenium) disease may be found in the writings of Marco Polo, the Venetian, descriptive of his travels in China in the 13th Century. Referring to the revision of Marsden's translation of the Travels of Marco Polo (10), it develops that upon reaching the district of Succuir in the general Province of Tanguth, Marco Polo noted that a most excellent kind of rhubarb was grown in a mountainous district there and sent to all parts of the world. He also wrote that to venture in this district with any beasts of burden, excepting those accustomed to the country, was to invite disaster. He observed that a certain poisonous plant indigenous to the locality, if eaten by the animals, had the effect of causing their hoofs to fall off.



Fig. 5. Fore feet of a severely "alkalied" cow.



Fig. 6. Hind feet of a severely "alkalied" cow.

He adds that, "Those of the country, however, being aware of its (the weed's) dangerous quality, take care to avoid it."

In a footnote the editor refers to a publication, *Ruins of Desert Cathay*, by Sir Aurel Stein, in which the latter mentions the wild rhubarb and also describes difficulties with his ponies due to poisonous forage in this region.

Trelease and Martin (13) state that there appears to be some variation in the selenium poisoning of livestock, depending upon the type of plant which has been consumed. They suggest that different plants may carry the poison in a number of variable chemical combinations and that, in some cases, other toxic substances may be present which may accentuate or perhaps supplement the injury actually caused by selenium. They mention that Draize and Beath distinguish two types of the disease in livestock, namely, "alkali disease" and "blind staggers." Alkali disease is a misnomer, the term originating years ago as a result of the belief at that time that the disease was caused by the "alkali" waters of the affected localities. Trelease and Martin (13) describe alkali disease as the milder form of selenium poisoning, a malady characterized by deformation and loss of hoofs and by a loss of hair. Blind staggers is the acute form of the disease. It is usually fatal to livestock and does not produce the hoof and hair symptoms of the milder form of the disorder. With both diseases, however, they state that injury to the liver of the animal is similar.

Moxon (8) states that, in general, alkali disease (chronic selenium poisoning) may appear in animals when their feed contains as little as from 5 to 40 parts of selenium in a million parts of feed. Symptoms of the disease may be observed a few days or weeks after the animal starts feeding regularly on the selenized diet. He adds that many ranchers have expressed the belief that by grazing for only one night in a seleniferous pasture or by eating one feeding of seleniferous grain horses may lose the hair from their manes and tails and, in some cases, they may lose their hoofs or become so lame that they can walk only with difficulty. Blind staggers, he states, is the acute form of the disease. Paradoxically, an animal suffering from blind staggers does not necessarily become blind nor does it invariably stagger about. In summarizing Draize and Beath's description of blind staggers, Moxon writes that in the early stages of the illness cattle tend to stray from the herd. There is a slight impairment of vision which interferes with the animal's judgment of distances of objects in its path. In the next stage vision becomes more impaired, the animal attempting to push solid objects to one side rather than go around them. Appetite becomes depraved with a desire to chew wood, bone and metallic objects. Final stages of the disease are characterized by paralysis, grating of teeth, salivation and grunting. The animal shows evidences of abdominal pain; death usually follows from failure of respiration.

Symptoms in animals similar to those described by Moxon for the chronic or milder form of the disease have been observed in Hawaii. Moxon states that dullness and lack of vitality are general symptoms and that the animals become emaciated, their coats become rough and their desire for food becomes less and less, even when moved to a non-seleniferous area. In advanced cases of this milder form of selenium disease, the heart and liver of the animals become severely damaged. Moxon mentions that cases of atrophy of the heart (dishrag heart) and atrophy and

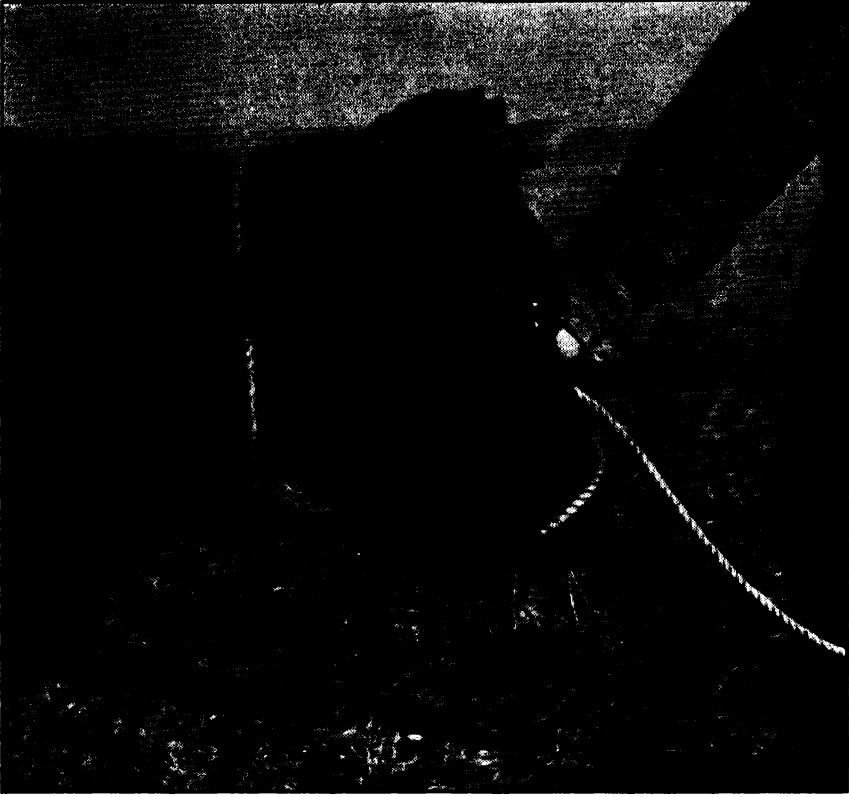


Fig. 7. Photograph of "alkalied" cow's head showing a ring on the horn which marks an interruption in the growth of the horny material similar to the interruptions in growth of hoof in Fig. 2.

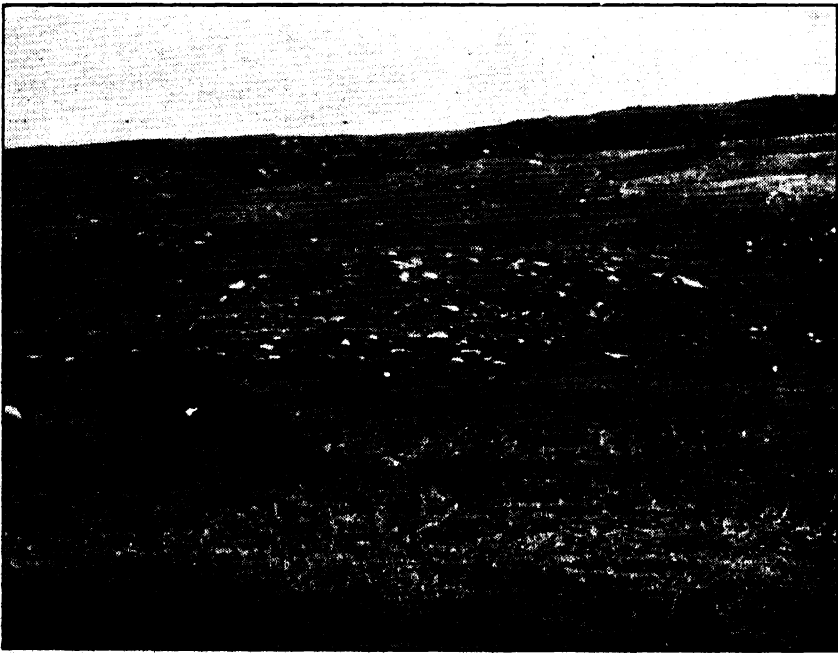


Fig. 8. A grazing scene showing an "alkalied" steer which has assumed a kneeling position, while grazing, to avoid standing on its fore feet which were badly diseased.

cirrhosis of the liver have been found in animals afflicted with the disease. Anemia is a common symptom; likewise erosion of the bones, especially the joints of the long bones, the animal's gait becoming stiff and halting. Moxon points out that the bone injury is accompanied by a disturbance of the calcium-phosphorus metabolism. It is of interest to note again that Thorp (12), in his discussion of soil studies made in China, suggested that a bone malady prevalent there in humans may have been due to selenium rather than to a deficiency of calcium and phosphorus in the soil.

Horses, cattle, hogs and poultry are susceptible to selenium poisoning.

*A. L. Moxon's description of the symptoms of the disease in each class of animals is given below. Mr. Moxon has very kindly forwarded the cuts used to illustrate the symptoms of selenium diseases in affected animals which came under his observations. With his permission these illustrations are repeated here for the benefit of Hawaiian readers.*

#### *Horses:*

First symptoms are loss of hair from tail and mane, followed by soreness of feet. A ring begins to show on the upper border of the wall of the hoof (coronary cushion). In severe cases the hoof may become partially separated at the line of the ring with new growth starting at this point. During the shedding period the animal is in pain and often will not move. Unless watered and fed, it will die of starvation. Colts born of selenized parents may have deformed hoofs and show other symptoms of the disease.

Severe or acute injury to horses by selenium poisoning occurs only in districts where deposits of selenium in the soil are comparatively high or where "converter" plants have been growing for some time. These symptoms have been described previously.

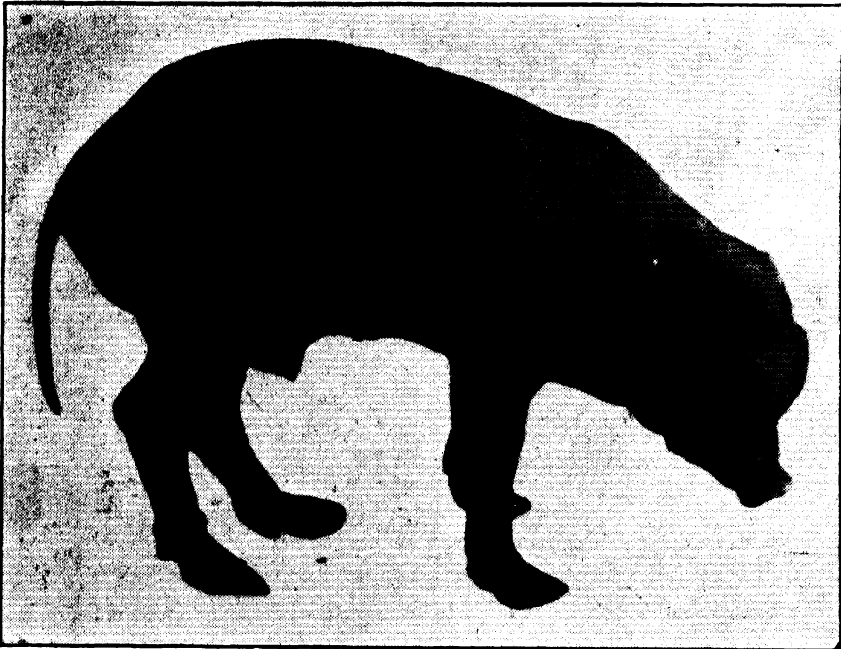
#### *Cattle:*

Early symptoms of the disease in cattle are lameness and loss of hair from switch. Hoof injury is similar to that described as occurring with horses. Animals will occasionally rest on their knees when grazing because of pain in the fore feet experienced in standing. Usually the old hoof does not shed completely but remains attached to the new growth. Cattle have been known to grow ragged hoofs extending eight to ten inches upward at the extremities. The horns of cattle will sometimes show ridges or rings comparable to the hoof injury. Their legs may become stiff due to bone erosion. Even in very mild cases of poisoning, where no hoof or horn injury is apparent, the animal may become emaciated and lose weight. Extreme emaciation (off feed and loss of weight) is common in more severe cases of the disease. Young calves may show common symptoms of the disease when born or the disease may develop during nursing. The milk from diseased cows may contain considerable quantities of selenium.

#### *Hogs:*

When fed selenized ration, hogs may become lame. Loss of hair, generally from the entire body, is quite common. In some cases hoof growth becomes irregular and shedding of hoofs occurs very much as in the cases of diseased cattle and horses.





**Fig. 9.** An "alkalied" pig. Notice the general run down condition, thinness of hair, and diseased feet.



**Fig. 10.** Day-old chick, hatched from an egg laid by a hen which was fed seleniferous grains. Notice the weak condition and wiry down.

Suckling pigs may be affected by the selenium transmitted from the mother in her milk.

#### *Poultry:*

Most damage to chickens by selenium poisoning appears to originate in the immediate progeny and to be manifested at hatching. For instance, hens may be fed grain grown on selenium soils without showing any ill effects whatever. Their eggs may be fertile, but are likely not to hatch well. On the other hand, they may hatch in a satisfactory manner but may produce deformed chicks with wiry down. Monstrosities are also hatched at times, having hideous deformations. The poultry phase of selenium poisoning has been given attention and study by several mainland research groups. Due to the belief that Hawaiian poultry has not been affected by the disease, no further discussion of this subject will be offered.

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*Leucaena glauca* (koa haole), a common nitrogenous Hawaiian plant acceptable to grazing stock, has been found by Mr. Hamamura in this laboratory to carry a higher percentage of selenium (1.4 p.p.m.) than a soil (0.25 p.p.m.) upon which the plant was growing. Other specimens of the same plant collected from non-seleniferous districts have been found to be free from selenium.

Observations are common in Hawaii on loss of mane and tail in mules and horses and complete loss of hair in hogs which have been fed *Leucaena glauca* from certain districts. An investigation is now in progress, the object of which is to obtain specific information on this point in connection with the presence or absence of selenium in soils and associated plants, a factor which may have contributed to the cause of disorder in these animals. The investigation will include a general survey of Hawaiian soils including prevailing local vegetation as suggested by Byers, et al (1). L. R. Smith, Associate Agriculturist, E. L. Caum, Associate Botanist, and Mr. Hamamura, Assistant Chemist, have agreed to cooperate with the author in this study. The findings will be presented in a future issue of the *Record*.

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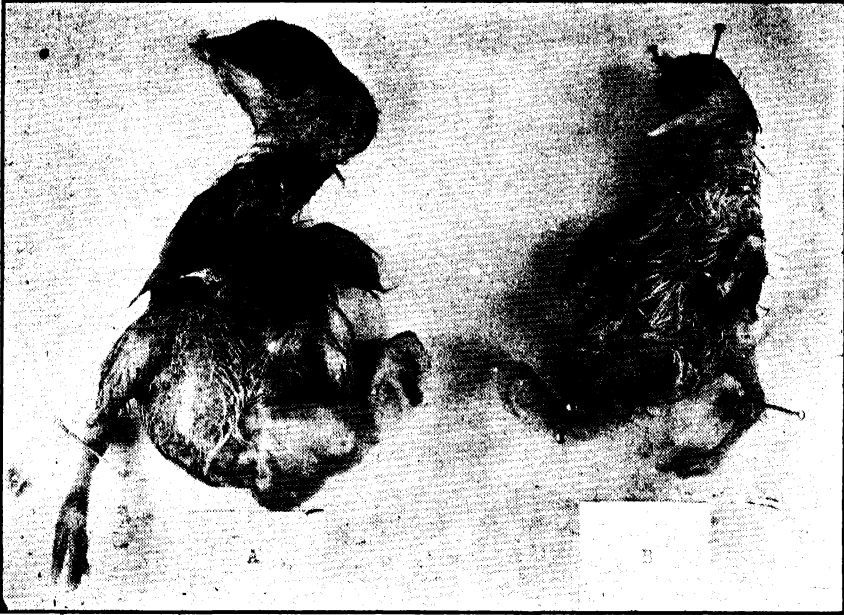


Fig. 11. Two chicks which were alive (in the shells) on the twenty-third day.

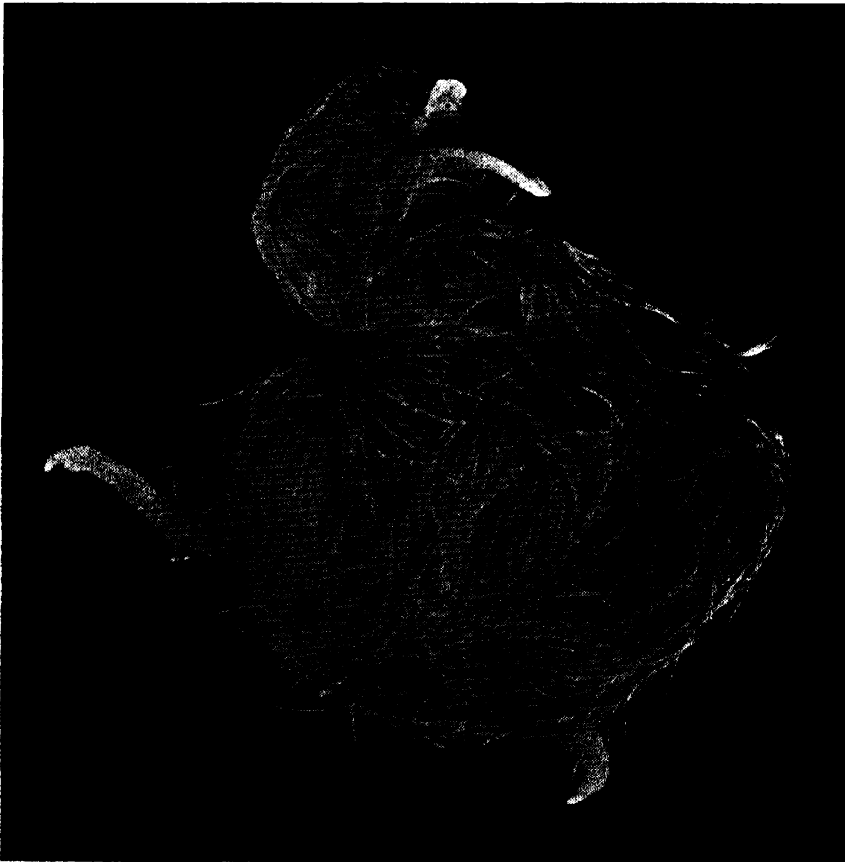


Fig. 12. A typical deformed chick. Notice the eye, beak and foot deformities and the absence of wings.

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Fig. 13. "Alkalied" chick, eyes and upper beak missing, feet deformed.



Fig. 14. "Alkalied" chick from series 3.

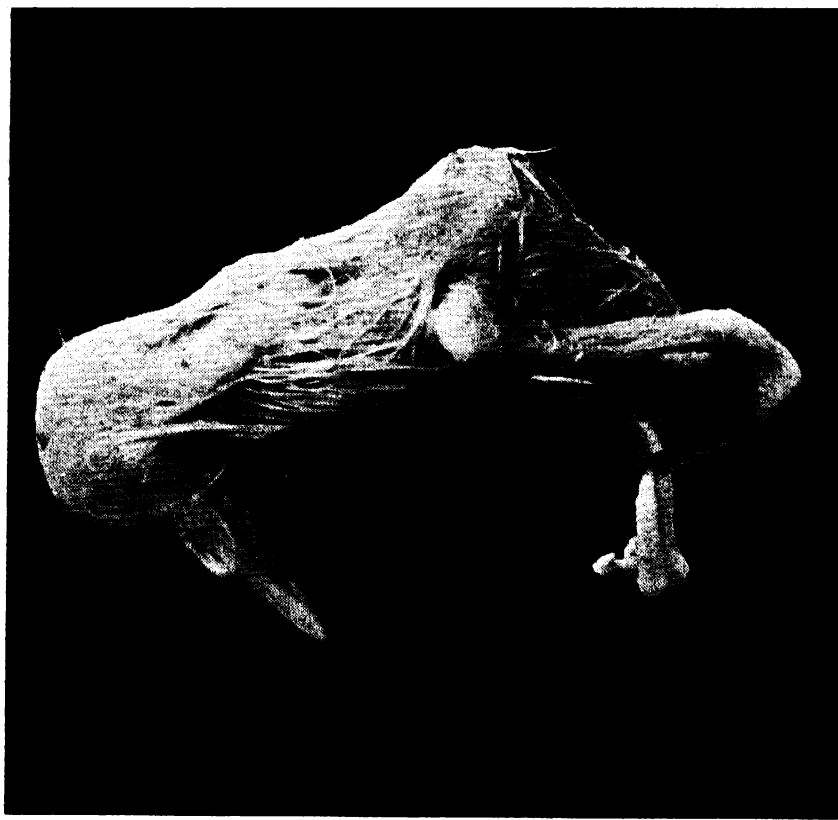


Fig. 15. Deformed embryo resulting from the injection of .01 p.p.m. of selenium into the air cell of a fertile egg before incubation.

# Some Insect and Other Animal Pests in Hawaii Not Under Satisfactory Biological Control

By C. E. PEMBERTON AND F. X. WILLIAMS

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## INTRODUCTION

Although a number of insect pests in the Hawaiian Islands have been brought under excellent control by biological methods, many others, and a few that are not insects, still occur which seriously damage plants of agricultural or ornamental value. Little attention has been given to their control by parasites, predators, diseases, etc., and it is probable that in some cases at least, the damage could be permanently checked by utilizing natural enemies which may be found in other parts of the world. In some cases parasites and predators, not already in Hawaii, are known. These should be introduced. In others it is quite possible that careful investigation would reveal control factors, unknown at present, which could be transported to Hawaii. Few within the Islands are aware of the entomological problems of economic importance that still require solution within the Territory. The object of the present paper is to summarize this information, in brief form, and offer suggestions, wherever possible, to serve as a guide to entomologists who may have opportunity to investigate any of these problems in the future. Most of the prominent plant pests which have few or no natural enemies of importance in Hawaii are included. The home, if known, the host plants, damage and known parasites and predators elsewhere, are given whenever possible.

## COMMON GARDEN SNAIL

*Eulota similis* (Férussac)

Adventitious in Hawaii. It occurs also in Eastern Asia, East Indies, Japan, South America and West Indies. There are many Asiatic species of *Eulota*. It is a flower and vegetable garden pest.

The larvae of species of lampyrid beetles feed upon various helicine snails. For *Lampyris noctiluca* of Europe, see Newport (73) and Fabre (22). A Philippine species was noted by Williams (120, pp. 102-103) feeding upon a snail that somewhat resembled a species of *Eulota*. In Europe and North Africa, the larvae of drilid beetles destroy many helicine snails, Mielzinsky (70), Crawshay (16), and Rosenberg (83). In Europe and North America, carabid beetles of the group Cychrinae prey upon helicine snails. The European calliphorid fly *Melinda cognata* feeds as a larva in living terrestrial snails, Schmitz (85), Keilin (55). For further information and summary see Bequaert (8).

## SUGAR CANE STALK MITE OR CANE RUST MITE

*Tarsonemus spinipes* Hirst

For some time confused here with the rather similar *Tarsonemus bancrofti* Michael, the Java sugar cane stalk mite, Pemberton (75).

*Spinipes* occurs in the West Indies, Peru, and the Hawaiian Islands.

The damage to sugar cane is most characteristic in the eye groove, the mite causing small reddening blisters on the surface of the young internodes while still ensheathed. This mite is suspected of causing galls on cane stems, Pemberton (76). Other species of the genus cause galls on plants. The eggs have been described by Carpenter (14).

There appear to be no known specific enemies of this mite, but the damage is generally not sufficient to warrant costly remedies.

## BLACK WIDOW SPIDER

*Latrodectus mactans* (Fabricius)

This is an American species favoring warmer climates. It occurs nearly everywhere in the United States, and ranges from Canada to Tierra del Fuego, Baerg (3). An immigrant to Hawaii where it was first reported by Hadden (39) in 1925. Now it is widespread in the more arid lowlands of the Archipelago. The female is the more venomous; its bite found to be occasionally fatal to man on the U. S. A mainland. One female often lays 1000 or more eggs, distributed in several cocoons.

*Enemies:* In Corsica, Fertou (25, pp. 164-165) noted the pompilid wasp, *Pompilus rytiphorus*, preying on the venomous *Latrodectes 13-guttatus*. The American blue mud-daubing wasp, *Chalybion caeruleum* (Linn.), a spider catcher and a recent immigrant in Hawaii, may store a goodly proportion of *Latrodectus mactans* spiders. Irving and Hinman (52). Pemberton (77) has found these spiders stored in the mud nests of *Sceliphron caementarium* (Drury) in Hawaii. It is possible that *Chalybion* wasps used the empty nests of *Sceliphron* for storing its spider prey, which is the usual habit of the former. Herms, Bailey, and McIvor in California (45) give a good account of *Latrodectus mactans* and of two of its parasites that feed within its egg cocoons; one of these parasites is a small chloropid fly, the other a braconid wasp of the genus *Gelis*. Jenks (53) gives a good illustrated account of the parasitic chloropid fly—known as *Gaurax araneae* Coq.—a California insect.

For a local account of the Black Widow see Illingworth (49). Dr. Nils P. Larsen (65) in Hawaii experimented on guinea pigs with the venom of the black widow. An effective remedy against the bite of the black widow is the intravenous administration of magnesium sulphate—see Frawley and Ginsburg (28). There are many other important references on the Black Widow.

## GARDEN CENTIPEDE

*ScutigereUa immaculata* (Newport)

The so-called garden centipede, *ScutigereUa immaculata*, is not a true centipede but “a centipede-like animal belonging to the class Symphyla, members of which are considered by some students as possibly ancestral to both insects (Class Insecta) and true centipedes (Class Chilopoda)” (121). It has been known in Hawaii for many years, but its correct identity was not established until November 1, 1928 (48). There is no evidence to indicate when or how it first reached Hawaii. It has a world-wide distribution. The original home is unknown.

This symphyliid seriously damages young pineapple plants in restricted soil area in Hawaii by eating out the growing root tips. The damage is often sufficient to almost kill the plants. Illingworth (47) has discussed this damage and the habits of the pest in detail. According to Wymore (121) it sometimes destroys large areas of asparagus in California unless expensive control measures are resorted to. The soft-bodied, pure white garden centipede is about ¼ inch long when mature. The 12 pairs of legs readily distinguish it from true centipedes.

No important natural enemies have been reported. Illingworth (47) has noted a staphylinid beetle *Philonthus discoideus* and a cucujid beetle *Cryptamorphia*



*desjardinsi* as preying upon this symphylid in Hawaiian pineapple lands. Wymore (121) mentions four species of true centipedes that feed on the garden centipede in California. Filinger (26) discusses two others that seem to be important control factors in greenhouses in Ohio.

#### THE SOIL-NESTING TERMITE

##### *Coptotermes formosanus* Shiraki

#### THE DRY-WOOD INHABITING TERMITE—HOUSE TERMITE

##### *Kalotermes (Cryptotermes) piceatus* Snyder

*Distribution:* *Coptotermes formosanus*, probably immigrant from the Orient, where it occurs in Japan, Formosa and South China. *Cryptotermes piceatus* perhaps indigenous in Hawaii, occurs also in the Marquesas, Light (66).

*Injury:* *Coptotermes formosanus*, the more injurious and rapid worker of the two, nests in large colonies underground and destroys woodwork in the ground as well as above, tunneling out large irregular galleries chiefly parallel to the grain of the wood. Long cover-ways may lead along cement walls, etc., to woodwork, far removed from the nest.

*Cryptotermes piceatus*, a smaller species, nests in walls of houses, furniture, etc., in relatively small communities, of which, however, many may be present in a given area. It works rather slowly.

Nearly any sapwood is liable to attack by termites although redwood (*Sequoia*) is relatively immune. Termites move from place to place naturally through nuptial flights. They are also distributed through infested lumber.

They are guarded against through poisons and termite proofing of buildings. Here in Hawaii they have few obvious enemies aside from the common *Pheidole megacephala* ant. Elsewhere in the tropics termite raiding ants, *Odontoponera transversa* Sm. of the orient, *Neoponera commutata* (Roger) of Brazil and *Megaponera foetens* F. of Africa, do some good in reducing these pests. These are large stinging ponerine ants and probably would not succeed in Hawaii. *Ochromyia* flies are also termite enemies, so are certain phorid flies. Ant-eaters and some birds consume quantities of termites. Nematodes and fungi may also be listed as parasites of termites. However, it appears that there has not yet been found an efficient natural enemy of termites.

Further references: Ehrhorn (20), Van Zwaluwenburg (115), Pemberton (74), and Williams (119, pp. 164-165).

#### BEETLE OR CYPRESS ROACH

##### *Diploptera dytiscoides* (Serville)

Described from Australia, also found in Fiji, New Guinea, Singapore, Ceylon, Marquesas, Ascension Isl., etc., and as an immigrant in Hawaii.

Of gregarious habit, it is sometimes quite injurious to *Cupressus* and *Cryptomeria* trees, the bark of which it gnaws, often with a girdling effect. It also attacks algaroba, lime, and other plants.

This roach is viviparous, thus eliminating the possibility of egg parasites. In Hawaii, *Bufo marinus* and probably the mynah bird feed upon it. No effective enemy, however, is known. In other countries some cockroaches are preyed upon by ampulicid and sphecid wasps. A rhipiphorid beetle attacks *Blatta germanica*, Stamm (91), and it is possible *Diploptera* has a similar enemy.

#### BURROWING ROACH

##### *Pycnoscelus surinamensis* (Linnaeus)

This roach is common, but not in habitations. It seems to have been first recorded from the Hawaiian Islands in 1882, although present many years previous. It is circumtropical in its distribution, but is found in subtropical regions also. Apparently of American origin, although several Asiatic species of the genus are known, Hebard (44, pp. 192-197). The insect produces no external egg capsule, but gives birth to a number of young at one time.

It is a vector of the eye worm of poultry, Alicata (1). It also does some injury to tender roots, tubers, and young plants.

In Hawaii, *Bufo marinus* feeds extensively on this roach and the mynah bird also preys upon it. In Haiti, the fly *Sarcophaga sternodontis* (Townsend) is a parasite upon it, Hoffman (46). This fly however is not a specific enemy. Ampulicid or sphecid wasps may perhaps prey upon this insect.

#### GARDEN GRASSHOPPER

##### *Atractomorpha ambigua* Bolivar

This insect was described in 1905 from Shanghai, China. It first appeared in the Hawaiian Islands in about 1900, Perkins (78).

Here it is chiefly a garden pest; in the Orient a related species is bad on tobacco seedlings, Maxwell-Lefroy (67, p. 119). The life history of our species is given by Swezey (92).

No specific enemies seem to have been recorded for this genus which is represented in the Orient, Australia, and in Africa. Parasites in the egg capsules of *Atractomorpha* are likely to occur, and certain sphecoid wasps (*Priononyx*) in America prey on short-horned grasshoppers of several genera, Williams (117, pp. 227-230).

#### TOMATO BLOSSOM BUG

##### *Cyrtopeltis varians* (Distant) (*Engytatus geniculatus* Reuter)

First recorded from the Hawaiian Islands in 1924 by Swezey (99). General here at lower levels. Described from Guatemala. Probably native to tropical or subtropical America.

Damages tomatoes—sucking the flower stems, causing the flowers to drop off and the fruit not to set. Also breeds on tobacco here and in tropical America. Illingworth (50) has done work on its life history. This bug may also be predacious, Illingworth (51), Rosewall (84).

No specific enemies of this bug seem to have been recorded. Should it have parasites it might prove dangerous to introduce some of these in view of the fact that *Cyrtorhinus mundulus*, our most efficient sugar cane leafhopper enemy in Hawaii, belongs to the same family (Miridae) as this tomato blossom bug.

#### CORN LEAFHOPPER

*Peregrinus maidis* (Ashmead) (*Pundaluoya simplicia* Distant)

A species of practically pantropic distribution occurring also in Southern United States and Hawaii, Muir (72, p. 147). Its native home is in doubt. In Hawaii it has been quite injurious since about 1880, Giffard (35, p. 116). Found on *Zea mais*, *Cynodon dactylon*, *Bromus unioloides*, *Sorghum vulgare*, and occasionally, *Saccharum officinale*, Kirkaldy (56, pp. 406-407). It stunts corn plants, and is the vector of corn stripe disease, Kunkel (64).

Fullaway (30, pp. 10-11) gives a brief life history of this insect in Hawaii.

In Guam, Swezey (107, p. 308) found *Cyrtorhinus lividus*, a leafhopper egg-sucking bug associated with *Peregrinus maidis*. In 1915, H. T. Osborn introduced the mymarid wasp *Paranagrus osborni* Fullaway from the Philippines. *Anagrus frequens* Perkins, parasitic in the eggs of the sugar cane leafhopper here also parasitizes *Peregrinus* eggs, Swezey (104, p. 290). Fullaway (32) reports having reared a dryinid wasp from the corn leafhopper.

#### THE COTTON OR MELON APHIS

*Aphis gossypii* Glover

The cotton aphis in Hawaii was first identified as such in 1909. It was common by that time and no doubt had already been in the islands for several years. It probably came to Hawaii from California where it has been known for over 50 years. It was first described from heavy infestations occurring on cotton in Georgia and South Carolina in 1854 and has subsequently spread to most of the states of the Union. It was early recorded on cotton in Brazil and to date is known to be present in most temperate and tropical parts of the world. It has a long list of host plants, numbering 50 or more, but is particularly destructive to cucurbits, such as melons, squashes and cucumbers, as well as commercial cotton and related plants. In Hawaii it has at times badly infested Irish potatoes, taro, cotton, hibiscus, eggplant, a number of ornamental garden plants and quite a list of weeds (113).

A number of predators and parasites attack this aphid in Hawaii, but more are known in various countries which would probably prove useful if introduced.

#### THE COWPEA OR BEAN APHIS

*Aphis medicaginis* Koch

The bean aphis has also been in Hawaii 30 or more years. It was first identified here as this species in 1910. It is considered to be of European origin. It feeds chiefly on legumes, but has been recorded on a fairly wide range of host plants. It probably reached Hawaii from California, where it is a pest of economic importance. Because of its ruinous effect on cowpeas in these Islands, it is listed here as one of our important pests, requiring further control with imported natural enemies.

## HIBISCUS WHITE FLY

*Aleyrodes hibisci* Kotinsky

This pest is rather generally distributed in the Territory of Hawaii where it was first recorded by Kotinsky (62, pp. 96-97). Kirkaldy (57) does not consider it endemic.

It is abundant on *hau* (*Paritium tiliacum*) and on hibiscus.

In Hawaii the aphelinid wasp *Encarsia* sp. has been reared from *Aleyrodes hibisci*, Timberlake (112, pp. 435-436) and to this Fullaway (33, p. 113) adds the wasp *Eretmocerus corni* Hald. which often severely parasitizes this *Aleyrodes*. For aleyrodid enemies elsewhere, see Barnes (5). Material of the Hawaiian Hibiscus white fly was sent to Dr. R. Takahashi, Entomologist of the Government Research Institute, Department of Agriculture, Taihoku, Formosa, who pronounced the Hawaiian species to be identical with the Formosan *Dialeurodes hibisci* in a letter to C. E. Pemberton dated December 17, 1934. Dr. Takahashi stated that it is not abundant in Formosa. For this reason it may have efficient parasites in that region.

## LANTANA BLIGHT—LANTANA SCALE

*Orthozia insignis* Douglas

A tropicopolitan insect and in greenhouses in temperate regions. Originally described from specimens on *Strobilanthes* "in the Royal Gardens at Kew," England. Its original home is doubtful. In the Hawaiian Islands, first found at Wailuku, Maui, by G. P. Wilder in 1899, Koebele (60). It damages a large number of dicotyledons, but is also reported from *Saccharum*, Morrison (71). An enemy of lantana in Hawaii.

The ladybeetle *Hyperaspis jocosa* (Muls.) was introduced into Hawaii from Mexico by Koebele in 1908 (63). At Nikko, Japan, Koebele (60) found a species of *Orthozia* attacked by *Hyperaspis* near *repensis*.

There appear to be no wasps parasitic on *O. insignis* known.

## GREEN COFFEE SCALE—GREEN BUG

*Coccus viridis* Green

Described from Ceylon. Now a practically tropicopolitan insect. Considered native to Brazil, Dammerman (17, pp. 250-251). In Hawaii it was first discovered in Kona, in 1905, on citrus fruits by Kotinsky (61). It is injurious to coffee, citrus, gardenia, ixora, cacao, etc. The sooty mold that develops from the attack of this scale aggravates the damage.

In the Hawaiian Islands, the tropical American ladybeetle, *Azya luteipes* Muls. introduced here in 1908 from Mexico, Swezey (103) is sometimes effective, as also—more or less—the Australian *Orcus chalybeus* Boisd, and *Chilocorus circumdatus* Shon from China. Of parasites, the chalcid wasp *Prococcophagus orientalis* (Howard) is probably the best here, Timberlake (110, p. 404). In Ceylon, Green (38, p. 202) reports *Ceraptocerus ceylonensis* Howard.

Periodically, fungus greatly reduces *Coccus viridis*.

## COCONUT SCALE

• *Pinnaspis buxi* Bouche (*Pinnaspis pandani* Ckll.)

This insect, described from Europe from *Buxus sempervirens*, in 1851, occurs also in the West Indies, Brazil, and in greenhouses in temperate regions. It has been in Hawaii for many years. It is found on many kinds of plants including palms, pandanus, dracaenas, araceae, etc. In recent years it has been very injurious to coconut palms in Hawaii.

There is no satisfactory natural control of this pest here, although the little lady-beetle *Cryptogonus nigripennis* Weise, introduced by O. H. Swezey from Guam in November 1936, is promising, having already become well established on *Pinnaspis buxi* on coconut palms on Kauai. Mr. Swezey is publishing on this insect in the forthcoming *Insects of Guam*.

Of natural enemies elsewhere, Barnes (6, pp. 321-322) records the larvae of two species of midges—both from Ceylon—as being reared from plants infested with species of *Hemichionaspis* (= *Pinnaspis*). D. T. Fullaway, Territorial Entomologist, found the coccinellid *Pentilia egena* Muls. and the discolomid *Coccidophilus citricola* Brèthes to be important predators on *Pinnaspis buxi* at Rio de Janeiro. Efforts are under way to introduce these beetles into Hawaii.

## LIMA BEAN POD BORER

*Maruca testulalis* Geyer

The lima bean pod borer *Maruca testulalis* was first recorded as occurring in Hawaii on January 4, 1923, when Swezey (98) reported the finding of an infested garden pea pod obtained in a local Honolulu market December 9, 1922. Later he found a specimen in the Bishop Museum which had been collected on Tantalus by Professor Mosely of Ohio during August 1922. Mr. Swezey has since found it developing in the flowers of *Sesbania grandiflora* and in the seeds within the pods of lima beans, string beans, peas, pigeon peas, and the "Cowitch" *Mucuna urens*. This insect is an undesirable immigrant to Cuba and Puerto Rico, but does not occur within continental United States. It is known also in Java, Malaya, India, Burma, Ceylon, Uganda, Mauritius, and Samoa. Effective parasites are apparently unknown. A few of minor importance have been recorded in Cuba. Although the aggregate damage caused by it in Burma is considerable, it is listed as a pest of minor importance (87). At least one parasite has been found attacking it in India (27, p. 134).

## CORN EARWORM

*Heliothis armigera* Hb. (*obsoleta* F.)

The corn earworm or cotton bollworm is a notorious pest of green corn, which has girdled the globe within the parallels of 50 degrees north and south latitude (81, p. 13). Owing to its wide distribution, covering a long period of historic modern time, its original home is shrouded in obscurity. It was originally described in 1793 by Fabricius from material collected in the West Indies and it first gained notice as a pest in America, rather than some other region (81, p. 15). It sub-

sequently was found in many parts of the world and thus may possibly be of American origin. It has been known in the Hawaiian Islands 40 or more years. Strangely its host plants in Hawaii, which are many, did not include corn until about 1927, when Swezey (102) first found a caterpillar feeding in an ear of green corn. Previously it had been found feeding on tomato, cotton, eggplant, the flower heads of several compositae, certain weeds and some grasses, hibiscus flowers and buds, and a number of other plants. Commencing about 1931, damage became serious on corn. At that time Mr. Swezey reported about 50 per cent of the green ears of corn which he examined were infested with the caterpillars. Up to the present time the injury to the ears continues heavy. Swezey (108, p. 196) reported on May 2, 1935, that "The caterpillars feed chiefly in the ears of green corn, scarcely an ear of recent years but what is affected by them."

There are but few records of parasitism among corn earworms in Hawaii. Swezey (109) has reported finding larvae parasitized by *Hyposoter exiguae* (Vier.) and *Frontina archippivora* Will. Parasites and other natural enemies have been found attacking this insect in nearly every country where it has been studied. They are especially numerous in the mainland of the United States and have been mostly summarized by Quaintance and Brues (81, pp. 107-126). Many of these would be worth trying in Hawaii. Simmonds (90) records an unidentified species of *Apanteles* in Fiji, which is believed to be an effective parasite.

#### COCONUT LEAFROLLER

##### *Omiodes blackburni* (Butl.)

The coconut leafroller is generally considered a native Hawaiian insect, although the damage caused by it to coconut leaves is often so great, especially before certain foreign parasites became established, that it may be an old immigrant to the Islands. It has not been discovered outside the Hawaiian Islands, although allied species, referred to the genus *Nacoleia*, occur on other plants, mostly in India, Ceylon, and Malaya, some of which are known to be well parasitized. In support of the belief that it is endemic to Hawaii, Swezey (100, pp. 206-208) points out that *O. blackburni* and five other Hawaiian species of *Omiodes* occur on native species of bananas in Hawaii and that *blackburni* may have been in Hawaii before the coconut palm was introduced.

This insect often seriously damages the trees on the windward side of the Islands. Prolonged trade winds from the northeast apparently prevent the parasites of the leafroller from operating effectively wherever the trees are exposed to the wind. Quite a number of parasites operate on the coconut leafroller in Hawaii. Without some of them the damage to coconut trees would be very much greater and more continuous than it is at present. The four introduced parasites *Microbracon omiodivorum* (Terry), *Brachymeria obscurata* (Walk.), *Frontina archippivora* Will., and *Trichogramma minutum* were cited by Swezey (93, p. 37) as being the most important natural control factors in 1907. About 1910 the Oriental parasite *Cremastus flavoorbitalis* Vier. appeared in the Hawaiian Islands and attacked many different lepidopterous hosts, but especially the coconut leafroller. Often a high percentage of the caterpillars on the coconut leaves was found parasitized. By 1915

an improvement about Honolulu was noted and by 1917 the leafroller was at times quite scarce. This improvement seems to have resulted from the work of this new parasite and continues sporadically to date. *Cremastus* has difficulty during windy weather. However, more parasites are needed.

It is possible that some of the parasites of species of *Nacoleia*, occurring in India, Ceylon, and Malaya might attack the coconut leafroller if introduced to Hawaii. Known parasites of *Nephantis serinopa* Meyrick, a caterpillar which commonly feeds on coconut leaves in India, might also be worth investigating.

#### THE TORTRICID LEAFROLLER

##### *Amorbia emigratella* Busck

This moth is considered a native of Mexico. It is also known to occur in Costa Rica and is probably also natural to other Central American regions. It is believed to have reached the Hawaiian Islands, probably from Mexico, about 1900. It was first identified as the Mexican species and named in 1909 by Busck (13) from material sent him by Mr. Swezey.

This insect rolls and feeds on the leaves of various trees, shrubs, vines and other plants. Fullaway (29, pp. 23-27) lists the following among its host plants: citrus trees, cotton, avocado, guava, rose, passion flower vine, tomato, papaia, cacao, sweet potato, and various indigenous plants in the mountains. J. F. Illingworth recorded the green caterpillars as common on young macadamia trees in Kona, Hawaii. Fullaway (29, p. 23) states that the wriggling, stout-bodied, green larvae sometimes become so numerous as to defoliate trees. Bryan (11) bred this moth from a caterpillar found boring in a seed capsule of an orchid (*Phaius* sp.) in Honolulu.

Several natural enemies attack this pest in Hawaii, but the control is not satisfactory. Various entomologists have recorded the following: *Nesodynerus rudolphi* (D.T.), *Odynerus nigripennis* (Holmgren), and *Pachodynerus nasidens* (Latreille), which store *Amorbia* and other larvae in their nests for larval food; *Trichogramma minutum* Riley, which is an egg parasite; the pupal parasites *Brachymeria obscurata* Walker and *Ecthromorpha fuscator* (Fabr.); the larval or possibly pupal parasite *Ephialtes hawaiiensis* (Cameron) and a predator *Xiphidiopsis lita* Hebard. Other parasites are most probably obtainable in Mexico or adjacent countries.

#### KOA SEED WORM OR LITCHI BORER

##### *Argyroploce illepidata* (Butl.)

The koa seed worm or litchi borer is one of the early immigrant insect pests of Hawaii, having been found in the Islands when the first entomological collections were made. Originally known here as *Cryptophlebia illepidata* (Butl.), it was not until 1910 that Meyrick (69, p. 218) established its identity as *Argyroploce illepidata*, a species known in South Africa, India, Southern China, and Australia. This was positive and final evidence to support the feeling that it was not a native Hawaiian insect. It is a pest of major importance to *Acacia koa* in Hawaii, since its larvae destroy from 50 to 90 per cent of the koa seeds, as determined by Mr. Swezey. It also commonly infests the seeds of *Acacia farnesiana*, litchi, macadamia nut husks,

and the fruits of several other plants. There are times when the litchi crop is seriously damaged.

Parasites which have been reared from this pest in Hawaii include *Cremastus flavoorbitalis* Vier, *Ephialtes hawaiiensis* (Cameron) and *Microbracon pembertoni* Bridwell. More natural enemies are needed. They may occur in South India or Southern China where the damage to litchi has been reported to be light.

#### THE CABBAGE WEBWORM

##### *Hellula undalis* (Fabr.)

The imported cabbage webworm is considered as serious a pest of cabbage in Hawaii as the cabbage butterfly. It was in Hawaii as early as 1892 (31). It probably came from California in cabbages, for it was known in Los Angeles in 1891-92 (15). The date of its entry into the United States is not known, but by 1897 it had gained prominence as a pest of cruciferous plants through the Southern States to California. It now has a world-wide distribution within tropic and temperate zones. The larvae mine into the midribs of the host leaves, penetrate the stems and may enter the heart or bud of the growing plant, which prevents normal growth. Young plants may thus be killed outright (31).

Fullaway (31) reports one parasite *Chelonus blackburni* as commonly attacking this pest in Hawaii. Chittenden and Marsh (15) record at least five natural enemies occurring on the mainland of the United States. These would be worth trying in Hawaii. A few parasites have been reported from other parts of the world. It has been mentioned as a pest of minor importance in India, Burma, and Ceylon (27, p. 132). These regions would be the most promising for study in a search for natural enemies.

#### THE BEAN BUTTERFLY

##### *Cosmolyce boetica* L.

The bean butterfly entered the Hawaiian Islands sometime prior to 1882. It is perhaps of Oriental origin, though it is now distributed over the whole of South and Central Europe, parts of Africa, Canary Islands, Madagascar, Western and Central Asia, Mauritius, Ceylon, India, Malaya, Java, Sumatra, Japan, and probably other parts of the Malay Archipelago and the Pacific. It is a pest of leguminous crops of many sorts. The larvae destroy the pods, seeds and flowers.

Two parasites of this insect are known in Hawaii but they are not sufficiently effective. The minute wasp *Trichogramma minutum* Riley parasitizes the eggs and Swezey (96, p. 105) reared the large ichneumonid *Ecthromorpha fuscator* (Fab.) from the pupae of the butterfly. Both parasites have many other insect hosts in the Islands. *Trichogramma minutum* is said to be effective on this pest in Sumatra. It may be a different strain or variety from the *Trichogramma* in Hawaii. Dr. F. X. Williams found parasites of related bean butterflies in the Philippine Islands in 1922. These were an ichneumonid which parasitizes the larvae, and an *Odynerus* sp. which stores its nests with lycaenid larvae (118, p. 175). The ichneumonid and the *Odynerus* were introduced into Hawaii and liberated but have evidently failed of establishment.



## CABBAGE BUTTERFLY

*Pieris rapae* Linn.

The cabbage butterfly, or cabbage worm, has been in Hawaii at least since 1898. It was positively identified by Meyrick (68) in 1904. Perkins (79, p. cxliv) writing in June, 1909, states: "The Pierid, *Pieris rapae* was imported with cabbages from California some 12 years ago." It is of European origin, having first appeared in Quebec, Canada, about 1860, the State of Maine in 1865, and by 1883 it had reached California. The larva feeds on cruciferous plants and is particularly destructive to cabbage.

Several natural enemies attack the cabbage worm in Hawaii, but additional control is needed unless the present established parasites gain considerable headway in the immediate future. Of the established parasites *Apanteles glomeratus* (Linn.) is probably the most important. It was imported into America from Europe in 1883 and from the Atlantic Coast to Hawaii in 1898 and 1928 (101) and from Japan in 1923 (106). Swezey (106) first found it established in 1934. This was at Kilauea, Hawaii. Dr. C. Schmidt reported its establishment on Maui in 1936 and Dr. F. G. Holdaway announced the recovery of this parasite on Oahu in 1938. The tachinid fly *Frontina archippivora* Will., attacks the larvae of a number of lepidopterous insects, including the cabbage butterfly, as demonstrated by Swezey (106). This fly has been in Hawaii at least since 1895. Another parasite *Brachymeria obscurata* (Walk.), introduced from Japan about 1895, has several lepidopterous hosts in Hawaii. It has been reared from the pupae of the cabbage worm. The large *Polistes* wasps, early immigrants to Hawaii, use chewed up portions of cabbage worms and other caterpillars as food for their young.

In the event the above parasites and predators do not accomplish a satisfactory control of this pest, other known parasites occurring in America or Europe would be worth trying in Hawaii. An important parasite *Pteromalus puparum* (L.) has been introduced from California and bred in large quantities for liberation, but has apparently failed of establishment. This work was conducted by the entomologists of the Territorial Board of Agriculture and Forestry during 1919.


## HIBISCUS MIDGE

*Contarinia maculipennis* Felt.

This midge recorded thus far only from Hawaii, Oahu, and Kauai, was first bred from hibiscus buds by Swezey in November 1931 (105). It distorts these flower buds and often causes them to fall off. It has also been found on buds of *Jasminium sambac* (Fullaway, 34).

There appear to be no parasites on our hibiscus midge although related species elsewhere are parasitized by chalcidid wasps. For data on these, see Ballard (4), Barnes (7), and Ferrière (23).

## HORN FLY

 *Hyperosia irritans* (Linnaeus)

This pest of cattle breeds in cattle manure. It is a biting fly and accumulating in large numbers on its host irritates and weakens it by its bites and feeding. Widely

distributed in Europe and occurring also in Asia Minor, it was first discovered in America in 1887, and in Hawaii in 1898, Koebele (59). The life history has been worked out by Riley and Howard (82) and by others.

Natural enemies are of two types: dung scatterers, and direct enemies (parasites and predators). A. Koebele was the chief worker here for Hawaii, see Swezey (94). One of the parasites introduced by him is the German braconid wasp *Bathymetis* sp. *Spalangia philippinensis* was introduced by Fullaway.

For enemies preying on the related *Lyperosia exigua*, not occurring in Hawaii, see Ferrière (24) and Handschin (41, 42, and 43).

#### MELON FLY

##### *Dacus cucurbitae* (Coquillett)

Introduced here from the Orient in about 1895, Back and Pemberton (2). It is well distributed in the Orient. Bezzi (9, pp. 96-97) considers it to be native of India. For its distribution see Shiraki (86, pp. 96-97).

Its plant hosts are chiefly Cucurbitaceae; but Solanaceae and certain Leguminosae (string beans and cow peas) are also attacked.

In Hawaii, the braconid wasp, *Opius fletcheri* Silvestri (89, p. 163) introduced from India in 1916 is a larval parasite. Other *Dacus* parasites exist in India, Hadden (40). For information on dacine flies in West Africa, see Van Zwaluwenburg (116, pp. 78-83) and in East Africa, see Bianchi and Krauss (10). None of the recently introduced fruit or melon fly parasites have yet been recovered.

#### PINEAPPLE BEETLE

##### *Carpophilus humeralis* (Fabr.)

Though not confined strictly to decaying pineapples and pineapple stumps, *Carpophilus humeralis* is vastly more abundant in pineapple lands than elsewhere in Hawaii. This beetle develops to literally millions in rotting pineapple stumps following harvest. From there they fly into cane lands where they develop in souring cane material and often become a general and aggravating nuisance to the labor in the fields. The beetles often mass at the cut ends of planted cane seed pieces underground and during the winter months, when germination is slow, hasten fermentation of the pieces and interfere with the germination.

This nitidulid beetle is considered native to tropical Africa, but has become cosmopolitan through the transportation of fruits and other plant material in which it can live when such hosts are moved in a spoiled or decaying condition. No parasites or other natural enemies occur in Hawaii. Silvestri (88) described and figured in 1915 an internal parasite which he discovered parasitizing nitidulid larvae of supposedly *Carpophilus* species, occurring in fallen fruit at Conakry, French Guinea, West Africa. This parasite should be tried in Hawaii.

#### THE CHINESE ROSE BEETLE (JAPANESE BEETLE)

##### *Adoretus sinicus* Burm.

The Chinese rose beetle, commonly called in Hawaii the Japanese beetle, is not a native of Japan. It is known to occur in Southeastern Asia, Java, Formosa,

Timor, and Hawaii. It is believed to have been introduced into Hawaii some years prior to 1896. It almost certainly entered in the grub stage in soil brought in from China. The adult heavily defoliates many ornamental plants, shrubs, trees, vines, and truck crops in Hawaii at certain seasons of the year. The grub apparently restricts its food to decayed organic matter.

A number of different parasites for control of this beetle have been introduced into Hawaii from the Philippine Islands, Formosa, and Japan without successful establishment. The Scoliid wasp *Campsomeris marginella* sub-species *modesta* Sm. (*Scolia manilae* Ashm.), introduced from the Philippine Islands for the control of *Anomala orientalis* in 1916, parasitizes the grubs of the rose beetle in Hawaii and accomplishes a very considerable reduction in the population of the pest, but the control is insufficient and more natural enemies are needed. The toad *Bufo marinus*, an introduction in 1932, is playing a further part in checking the beetle, but the establishment of additional predators or parasites is necessary.

#### FULLER'S ROSE BEETLE

*Asynonychus godmani* Crotch (*Aramigus fulleri* Horn)

This weevil was first recorded in Hawaii in 1894, Koebele (58). It occurs also in California, Mexico, Brazil, Argentina, Chile, the Azores, Portugal, Sicily, etc. It is considered of American origin. The adult is injurious to flowers and foliage of many kinds. On the mainland of the U. S. A. and in Brazil it is an injurious feeder on roots in the larval stage.

In Hawaii the larva of *Conoderus exsul*, our common click beetle, is an enemy of the young of Fuller's rose beetle in the ground.

Fossorial wasps of the genus *Cerceris* have long been known to store their deep tunnels in the ground with various groups of beetles, of which weevils are among the most common provender. These wasps are often not specific in the selection of this prey, family limits apparently being sufficient in some cases, Williams (119, pp. 152-153).

#### SWEET POTATO WEEVILS

*Euscepes postfasciatus* Fairm. (*E. batatae* Waterh.)

*Cylas formicarius* Fab. var. *elegantulus* Summers

These two weevils have been in Hawaii a long time. They probably arrived in imported sweet potatoes brought to the islands over 50 years ago. The larvae of both bore extensively in the tubers and often render them unfit for food. They also work in the stems of the plants. *Cylas formicarius* also readily breeds in the stems of the beach morning-glory *Ipomoea pes-caprae* (29, p. 29). Swezey (97) has found that *Euscepes postfasciatus* can breed in the stems of a Japanese morning-glory in Hawaii also.

*Euscepes postfasciatus* has been found in many of the West Indian islands, Brazil, British Guiana, Peru, Hawaii, Guam, Fiji, Caroline Islands, New Zealand, and China. A rigid quarantine is maintained in the mainland of the United States against sweet potatoes produced in countries where this pest occurs. No parasites

or other important natural enemies are known to attack this insect, though extensive search for such control factors has apparently not been made. It is assumed to be native to some South American region.

*Cylas formicarius* has a very wide distribution throughout the tropics and subtropics of America, Africa, India, the Orient, and Pacific islands. Two parasites of minor importance are known to attack it in the Philippine Islands (36, p. 278). Though generally considered indigenous to India, it is rated as a serious pest of sweet potatoes there. Several species of the genus are known in Africa, though no parasites have been recorded from them in that part of the world. It is possible that natural enemies may occur in Africa, however.

#### MANGO WEEVIL

##### *Cryptorrhynchus mangiferae* Fab.

The mango weevil was first seen in the Hawaiian Islands on July 5, 1905. J. E. Higgins found a pupa in a mango seed in Honolulu. Van Dine (114), writing in detail on its early history in Hawaii, world distribution and habits, expressed the opinion that it undoubtedly came to the Islands after 1898 and that it was most probably introduced in mango seeds or other plant material imported from India or the Philippine Islands. This weevil has a wide distribution within the tropics, which includes parts of Africa, Madagascar, India, Ceylon, Java, Malaya, Philippine Islands, and Hawaii.

A high percentage of mango seeds in Hawaii is usually infested with the larvae of this weevil. The larvae enter the seeds of green fruit and it is generally conceded that such infestation induces a premature falling of the fruit. Van Dine states that no natural enemies of this insect have been observed. Like the mango, it is probably of Indo-Malayan origin and natural control factors such as parasites and predatory enemies, may be expected to occur somewhere within this region. Species assigned to the genus *Cryptorrhynchus* are, however, most numerous in South and Central America.

#### ORCHID WEEVIL

##### *Orchidophilus aterrimus* Waterh. (*Acythopeus aterrimus* Waterh.)

This dull black weevil, measuring from 1/8 to 1/7 inch in length, is the largest of the several species of orchid weevils that have been found in Hawaii at various times on orchids imported from several countries. It was evidently introduced in orchids imported from the Philippine Islands about 1910 or earlier. Swezey (95) records the first proof of establishment on May 5, 1910. This species attacks a wide range of orchid species, comprising a number of genera. It is now well entrenched in Hawaii both in greenhouses and outdoors. Dr. H. L. Lyon finds it infesting the common *Spathoglottis plicata* outdoors. The adults feed on the young leaves and flowers but the serious damage is done by the larvae which bore extensively in the pseudo-bulbs.

Buchanan (12) is of the opinion that the genus is indigenous in the upper Malayan region because of the frequency with which *aterrimus* and the other species of the genus are taken from orchids imported from the Philippine Islands or the

Straits Settlements. It is here that parasites probably occur, though none have been recorded.

#### CARPENTER BEE

##### *Xylocopa varipuncta* Patton

The carpenter bee *Xylocopa varipuncta* was common in the vicinity of Honolulu as long ago as 1880. Its correct identity was established and announced by Timberlake (111) at a meeting of the Hawaiian Entomological Society on January 6, 1921. This bee is considered an important pollinator of edible *Passiflora* species in Hawaii, but it bores so extensively in building timbers, fence posts, telephone poles, etc., especially if such are made of California redwood *Sequoia sempervirens*, that it is rated a pest of considerable importance by many residents of the Territory. The bee is native to Southwestern United States. Members of the family *Xylocopidae* occur mostly within the tropics and semi-tropics of such widely separated regions as Europe, Africa, Asia, India, Malaya, and the Americas.

A number of natural enemies of bees of the genus *Xylocopa* are known. The meloid beetle *Cissites auriculata* Champion destroys *Xylocopa* nests in tropical America. This beetle was introduced into Hawaii from Guatemala by F. A. Bianchi in 1935, though to date there is no evidence of establishment. Green (37) has described the habits of a similar beetle *Cissites testaceus* F. occurring in nests of *Xylocopa tenuiscapa* Westw. in Ceylon. The callimomid parasite *Monodontomerus montivagus* Ashmead has been recorded (18) as a larval parasite of *Xylocopa orpifex* Smith in Southern California. Two species of bombyliid flies *Spogostylum delila* (Loew) and *S. simson* (Fabr.) are known as natural enemies of the same carpenter bee in California (21), together with a mite *Trichotarsus xylocopae* Donn. ?, which was found attacking larvae of *Xylocopa varipuncta*. Asilid flies of the genus *Hyperechia* have been found developing within *Xylocopa* burrows in India and East Africa with definite evidence that their larvae fed on the bee larvae (80), (54). Dover (19) and Kannan (54) have discussed a minute encyrtid parasite, whose larvae completely fill *Xylocopa* larvae in British India. Mr. Pemberton reared hundreds of quite a similar parasite from *Xylocopa* larvae collected at Menado, North Celebes, during 1926.

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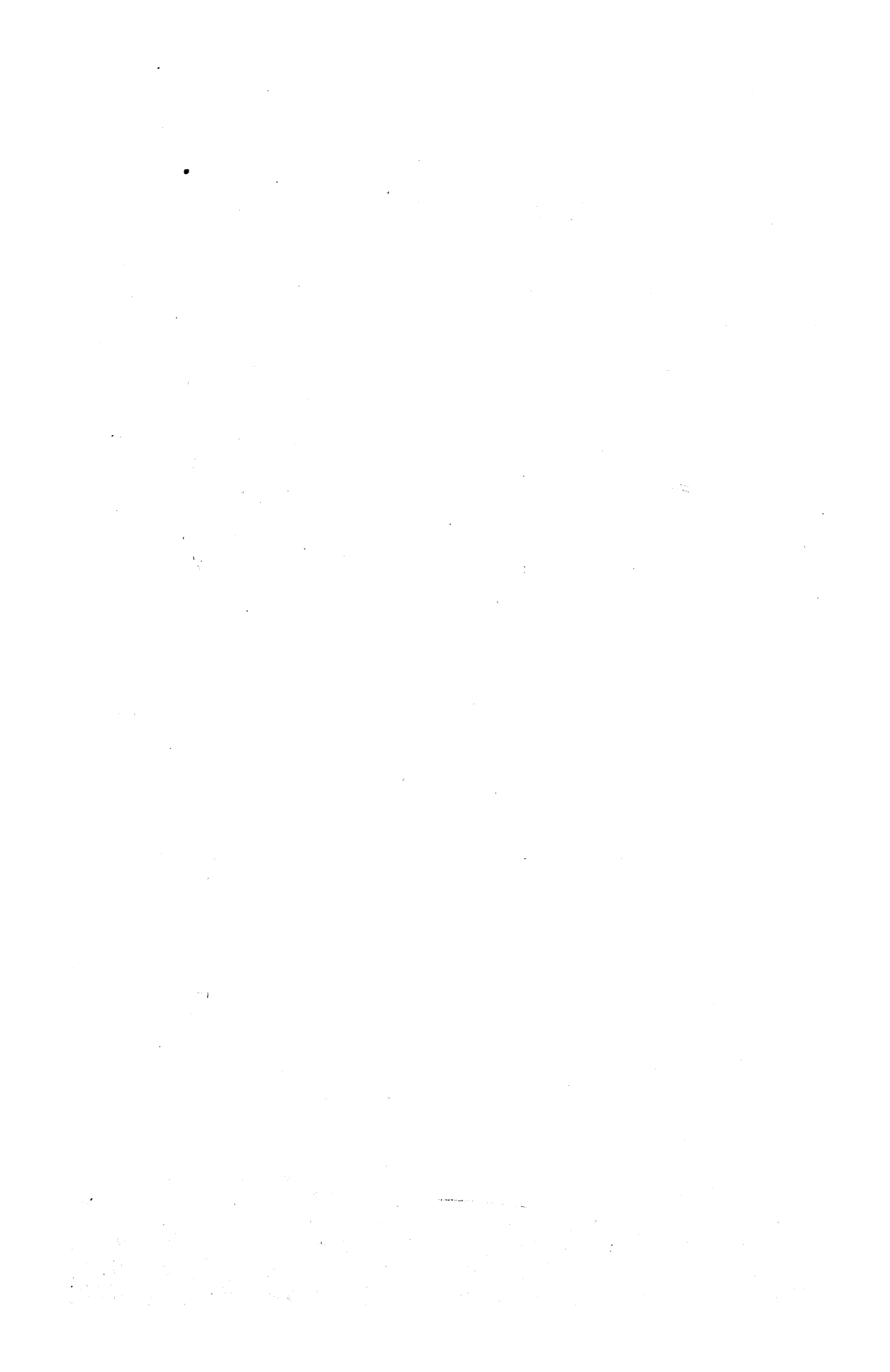
## Sugar Prices

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96° CENTRIFUGALS FOR THE PERIOD  
MARCH 16, 1938 TO JUNE 14, 1938

	Date	Per Pound	Per Ton	Remarks
Mar.	16, 1938..	3.01¢	\$60.20	Philippines.
"	20 .....	3.05	61.00	Puerto Ricos.
"	22 .....	3.005	60.10	Philippines, 3.01, 3.00.
"	24 .....	2.965	59.30	Philippines, 2.97, 2.96.
"	29 .....	3.00	60.00	Puerto Ricos.
Apr.	4 .....	2.98	59.60	Puerto Ricos.
"	5 .....	2.96	59.20	Cubas.
"	6 .....	2.95	59.00	Puerto Ricos, Philippines.
"	8 .....	2.89	57.80	Puerto Ricos, 2.90; Puerto Ricos, 2.88; Cubas, 2.88.
"	11 .....	2.855	57.10	Puerto Ricos, 2.86, 2.85; Philippines, 2.85.
"	12 .....	2.815	56.30	Puerto Ricos, 2.82; Philippines, 2.82, 2.81.
"	22 .....	2.81	56.20	Puerto Ricos.
"	23 .....	2.80	56.00	Philippines.
"	27 .....	2.835	56.70	Puerto Ricos, 2.85; Philippines, 2.82.
"	29 .....	2.81	56.20	Puerto Ricos.
May	2 .....	2.82	56.40	Puerto Ricos.
"	3 .....	2.805	56.10	Philippines, 2.80, 2.81.
"	5 .....	2.80	56.00	Philippines.
"	6 .....	2.75	55.00	Philippines.
"	18 .....	2.70	54.00	Puerto Ricos, Philippines.
"	20 .....	2.68	53.60	Philippines.
"	23 .....	2.65	53.00	Philippines.
June	3 .....	2.70	54.00	Puerto Ricos.
"	6 .....	2.72	54.40	Puerto Ricos.
"	7 .....	2.70	54.00	Philippines, Puerto Ricos.
"	9 .....	2.715	54.30	Puerto Ricos, 2.73, 2.70; Philippines, 2.70.
"	14 .....	2.70	54.00	Philippines.

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# THE HAWAIIAN PLANTERS' RECORD

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*A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.*

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## **In This Issue:**

### *Sugar Cane Collecting in New Guinea During 1937:*

A resume is given of the likely centers of origin of the various sugar cane species. The history of previous cane collections in New Guinea is detailed in full and is accompanied by a map showing the regions where collections were made by some of the expeditions.

The findings of an expedition sent into the Mandated Territory of New Guinea by the Hawaiian Sugar Planters' Association in 1937 are described. This expedition collected only seed-bearing fuzz which was stored in airtight containers and later germinated under the quarantine regulations of the Experiment Station, H.S.P.A. Particular emphasis was placed on the species of *S. robustum*, for it was desired to increase the range of this species in the breeding collection. The expedition arrived during February of 1937 which is the start of the tasseling season for this country. Its explorations were centered in four geographical areas:

(1) The rivers of the Gazelle Peninsula on New Britain yielded some interesting new *S. robustum* material which was characterized by freedom from pith in the stalks and bristles on the leaf sheath. One clon common on the pumice slopes carried desirable characteristics of light tasseling habit and continuous growing ability.

(2) The islands of New Ireland and Lavongai: A three weeks' survey through this region yielded no new forms of *S. robustum* beyond those which had already been found on the Gazelle Peninsula.

(3) Plateau country: The rolling grassy plateau (elevation 5500 feet) at the headwaters of the Ramu River on the mainland of New Guinea was found to be populated with a wide assortment of *S. robustum*, *S. spontaneum*, and apparent intermediates between these two. The seedlings derived from these collections show unusual vigor and a wide range of growing habit.

(4) Coastal rivers of Northern New Guinea: Collections were made on the river banks and swamps bordering the Francisco and Markham rivers.

Varieties of *S. officinarum* were found in all the native villages from sea level to the plateau country. In nearly all cases these were low fiber, soft canes whose juice by the hand refractometer showed Brix readings of 10 to 15. However, two varieties were found with Brix readings over 20.

Fiji disease was common throughout the territory on both varieties of *S. officinarum* and *S. robustum*. Downy mildew was noted on a few clumps of *S. officinarum* growing near the headwaters of the Purari River (elevation 600 feet).

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*An Annotated List of the Fungi and Bacteria Associated With Sugar Cane and Its Products:*

The check list of sugar cane fungi prepared by E. L. Caum and published in 1921 by this Station has proved extremely useful as a reference to organisms attacking sugar cane in the various sugar producing countries. Since 1921 many new fungi have been determined and numerous changes have been made in the nomenclature and classification of the sugar cane fungi.

The authors, in preparing the annotated list of fungi and bacteria associated with sugar cane, have in general followed Caum's plan. The fungi are arranged in alphabetical order according to their scientific names. Each organism is briefly described and its geographic distribution, "insofar as reported on *Saccharum* spp.," is given. The name by which each disease is commonly known, e.g., eye spot, brown stripe, smut, etc., is given in italics on the right margin of the page under the species name of its causal organism.

The compilation of the revised list has been an arduous task and will be invaluable to pathologists throughout the world as a standard reference to sugar cane fungi and bacteria.

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## Sugar Cane Collecting in New Guinea During 1937\*

By C. G. LENNOX

### INTRODUCTION

Genes are the plant breeder's building blocks. His chances of producing a desired type of plant depend largely upon the range of genetic material he has to work with, and it follows that the greater the range of his breeding material the greater are his chances of success. The recognition of this fundamental principle has led the plant breeder to add to his breeding gardens as many types as possible of the plant family with which he is working.

The early breeders working with the sugar cane plant confined their efforts to crosses between varieties of *S. officinarum*. As time went on it was seen that resistance to certain diseases was not obtainable within this species alone. The workers in Java were the first to attempt inter-species crossing with an object of introducing resistance to Sereh disease by crossing *S. officinarum* with *S. barberi*. This line of attack not only yielded resistance to the disease, but was found to give additional vigor, the like of which had not been obtained in working within *S. officinarum*. Inter-species crossing has progressed apace since this time and today is the foundation of all sugar cane breeding.

### ORIGIN OF THE SACCHARUM SPECIES

Exploration work on many of the economic plants which are under study today has revealed that they have had their center of origin in some rather restricted region of the world. These centers are characterized by an exceptional abundance of varieties and forms. Distribution from these centers may be accounted for by migrations of man, where the plant was of economic importance to him, or by natural agencies such as birds and winds. It naturally follows, therefore, that as we recede from these centers of origin we find the plant in question expressed in fewer forms. With sugar cane, the center of origin for the genus as a whole appears to be extended over the large area sweeping westward and northward from New Guinea through the Dutch East Indies, Malaya, Indo-China, and India. The centers of origin for the species within the genus *Saccharum*, however, are more localized, and in some cases do not overlap. The following is an attempt to localize the centers of origin for the various species with the information which is at hand today.

*S. officinarum*: This species has held an important position in the life of primitive man living in the tropics and has been widely distributed with native migrations. It is therefore difficult to place the center of origin within a confined area, as today it is found in great variation in the native gardens extending from Hawaii westward through India. However, in view of the much greater variation found in the gardens of the primitive peoples of New Guinea and the East Indies one may assume that the origin was in this general region.

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\* Presented at the meeting of the International Society of Sugar Cane Technologists held in Baton Rouge, Louisiana, October 25 to November 5, 1938.

*S. spontaneum*: This member of the genus *Saccharum* holds little of economic importance to man, and its distribution could hardly be placed at his door. However, the seed of this variety is exceedingly viable and its distribution has likely been through the agency of true seed carried by wind or by migratory birds. Forms of *S. spontaneum* are found all the way from the Solomon Islands through New Guinea, East Indies, Philippine Islands, China, India, Afghanistan to North Africa.

*S. barberi* and *S. sinense*: The small-stalk, heavy-tillering varieties of British India, South China, Indo-China, and Malaya have been lumped under these two species. The classification is a crude one at best with no clearcut morphological characteristics and great variation in chromosome counts (3). India is likely the center of origin for this group.

*S. robustum*: In view of the present information, New Guinea appears to be the center of origin of this species. Here it is found growing on the mud banks of nearly all the rivers in a profusion of variation. There appears to have been only a little spread of this species westward (Tananggé of the Dutch East Indies and Teboe Salah of the Celebes), and this may have been done by primitive man who prizes it for building purposes. However, it is found in the wild state, but in reduced variation, from New Britain through the Solomons and New Hebrides (2), as far southeast as Fiji\*. Some of this movement may have been with true seed carried by birds and some were likely carried as cuttings by migrating natives.

It is interesting to speculate on the relationship of *S. robustum* and *S. officinarum* in the evolutionary picture. Their similarities in stalk size, tillering habit, tassel structure, and chromosome number lead one to believe that they are related. Could they have come from a common ancestor whose hard rind, fibrous mutants have continued to survive in the wild, while the soft rind, juicy mutants were recognized by man and propagated under his care? If such was the case it is likely the varieties of *S. officinarum* are the result of a series of mutations selected for their easier chewing qualities. It is not likely that the varieties of *S. officinarum* as we know them today would have survived in the wild.

#### THE HISTORY OF CANE COLLECTING IN NEW GUINEA

The sugar cane growers of Queensland, Australia, have long been aware of the wealth of varieties that may be found in the gardens of the primitive natives of New Guinea. Repeated expeditions (see map) have been sent out by that Commonwealth for the purpose of collecting cuttings from these native gardens and testing their merits for commercial cultivation of sugar.

The first record is that of Cowley's (3) collection made prior to 1895 and introduced into Australia by the Queensland Department of Agriculture. Eleven named varieties were in this collection, but apparently none of them were suitable for commercial cultivation as they do not appear in the literature of recent years.

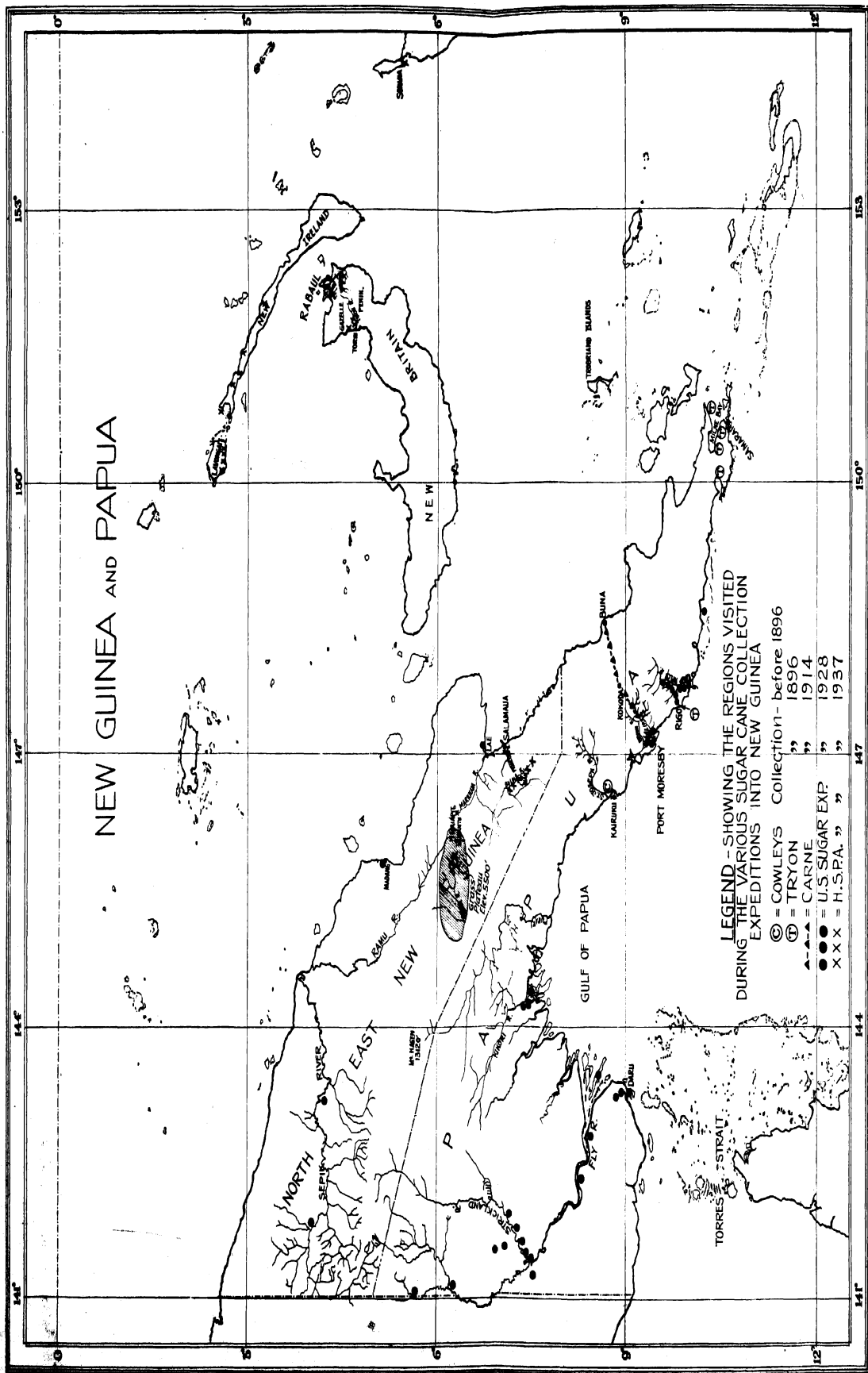
The second expedition was made by Tryon in 1896 under the auspices of the Queensland Department of Agriculture. Seventy-two named clons were intro-

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\* The writer identified a native Fijian variety (Daruka) as of the *S. robustum* species. O. W. Stevensen of the Colonial Sugar Refining Company has since written that he has found eight varieties of *S. robustum* on Viti Levu. Three develop normal tassels and five are of the edible tassel type.









duced, which were given N. G. serial numbers. N. G. 15 (Badila) is the most noteworthy of this group and still occupies a very important place in the variety census of the Australian sugar industry. N. G. 24 (Goru) and N. G. 22 (Mahona) are individuals which have also played a minor part in the commercial sugar world.

A third introduction was made in 1912 by the Queensland Bureau of Sugar Experiment Stations. A total of 119 clons were collected by Wells for this introduction. Only six were distributed by the experiment station for field trials, but none are in evidence today in commercial plantings.

The Colonial Sugar Refining Company sponsored an expedition under Carne in 1914. He collected cuttings from 103 clons. Three of these because of their disease resistance are still grown in commercial areas, i.e., 14 N. G. 190 (Oramboo), 14 N. G. 241 (Nanemo), 14 N. G. 124 (Korpi). Carne again found Badila, which he brought back under the number 14 N. G. 188.

In 1928 the United States Sugar Cane Expedition under E. W. Brandes, J. Jeswiet, and C. E. Pemberton, collected cuttings of 288 clons (4) over a wide range of territory. The collection not only included varieties of *S. officinarum*, but also had representatives of *S. spontaneum* and *S. robustum*. This is the first record of the latter species and first recognition of the wild river canes of New Guinea as belonging to the genus *Saccharum*. Representatives of this collection are found in the breeding gardens of the Colonial Sugar Refining Company at Macknade, Queensland, and Rarawai, Fiji, as well as in the U. S. D. A. collection at Canal Point, Florida. This expedition was the first to enter the New Guinea territory with an eye to securing breeding material as well as clons which would be suitable for commercial production of sugar.

The Hawaiian Sugar Planters' Association introduced in 1929 seed-bearing fuzz collected by Mr. Pemberton from *S. robustum* growing in the vicinity of Rabaul, New Britain. One seedling was raised from this, which appears in the cane breeding gardens of this Association. Mr. Pemberton also sent cuttings of the Rabaul *S. robustum* to the Colonial Sugar Refining Company in Australia.

In 1930 the Hawaiian Sugar Planters' Association made another introduction of seed-bearing fuzz of *S. robustum* which P. Leigh collected along the banks of the Laloki River near Port Moresby, Papua. Some 300 seedlings were retained for their breeding collection from the many thousands which germinated.

#### 1937 EXPEDITION INTO THE MANDATED TERRITORY OF NEW GUINEA

The breeding work in Hawaii is carried on along the same lines as that in other countries in which the strategy of inter-species crossing has been used to establish characteristics most urgently required for the systems of agriculture practiced. As an example, under the regions of low sunlight and heavy rainfall, the characteristic of heavy tillering for weed control has been of paramount importance. *S. spontaneum* and *S. sinense* have been valuable in crossing with *S. officinarum* to give this characteristic. For regions of heavy tonnage and long growing periods the importance of stalk durability and second-season growth has been emphasized by the failure of the *S. spontaneum* blood to transmit these characteristics. On the other hand the seedlings derived from the *S. robustum* combinations show a high proportion of hard durable canes. It was with this information and the natural de-

sire of the geneticists to increase their range of genes that an expedition was organized under the leadership of Mr. Pemberton and the writer to search the Mandated Territory of New Guinea for all forms of sugar cane which would be of interest in enlarging the scope of the breeding collection. Particular emphasis was to be placed on the species *S. robustum*.

The expedition set forth in time to arrive in New Guinea at the beginning of the tasseling period (February). Since the collection of breeding material was our main objective, a wider assortment could be had by bringing in seed-bearing fuzz rather than cuttings. The Experiment Station's quarantine facilities permit the handling of only 16 varieties at a time from cuttings, while three or four thousand seedlings from true seed can be accommodated. Moreover, the risk of introducing disease or insect pests is greatly reduced with true seed.

A brief description was made of all clons at the time the tasseled material was collected. This aided in avoiding duplication as it was often found that a clon had been widely distributed by natives.

The techniques used in collecting and preserving the fuzz were modifications adopted from the routine used in the ordinary crossing work in Hawaii. Wherever tassels were found sufficiently mature to harvest immediately they were cut and then dried for two days in paper bags before stripping off the fuzz. This dried fuzz was immediately packed in small gauze bags that were in turn placed in friction top, airtight tins. A small quantity of calcium chloride (approximately 5 grams  $\text{CaCl}_2$  per 10 grams of fuzz) was added to each tin. The covers were sealed with paraffin and where cold storage facilities were available they were stored at temperatures not lower than 38 degrees F. It often happened that the tassels were not at the right stage for harvesting. In such cases the stalk bearing the tassel was cut at a point about four feet below the last green leaf and the ends immersed in a weak solution of sulfurous and phosphoric acids. Sections of automobile inner tubes vulcanized at one end made convenient receptacles for carrying these bundles of tasseled stalks out of difficult places and back to headquarters. At headquarters the bundles were opened and the stalks stood in this solution (Fig. 1) until the tassels were ready for harvesting.

The area covered during three months in the Territory of New Guinea may be divided into four geographical regions, and will be discussed accordingly. The material collected has passed through the six-month quarantine period in an insect-proof greenhouse and is now planted in our quarantine field on the island of Molo-kai. The plants are old enough now for us to make general observations on the relative merits of the different collections, so in discussing each region general observations will be made on the appearance of the seedlings in the quarantine plot.

1. *Gazelle Peninsula, New Britain*: The Gazelle Peninsula is the northern fourth of the island of New Britain and is approximately 50 miles long by 50 miles wide, with Rabaul situated on the northern tip. An automobile road makes accessible an area within 30 to 40 miles of the town; elsewhere trading schooners must be used for transport. The whole peninsula is mountainous, the tallest peak being about 4500 feet.

The lower reaches of the three large rivers which drain this area were found to be populated with *S. robustum*, while on the upper reaches where the jungle overhangs the river it was found that the wild cane was unable to survive. Each river

had its distinctive type, although in general characteristics they were much alike. All tended to hold their trash. The stalks of the Toriu and Warangoi rivers forms were quite free of pith and the leaf sheaths free of spines. These characteristics are greatly desired as most of the *S. robustum* in the collection at present have these undesirable qualities. The forms found on each river were so alike morphologically that it would appear that they had been derived from a single clon—clumps of which had been torn away by floods and had been transplanted to the lower reaches. This similarity cannot be attributed to homozygosity as the seedlings which have been derived from them show a wide range of variation. At the present time the seedlings of the Toriu River collection show a high proportion of desirable types many of which approach the noble canes in stooling habit and leaf size.

The forms found growing away from the rivers cover two general classes, an erect, self-stripping, tall-growing, light-tasseling type (N. B. 2 and N. B. 3), and a trashy, lodging type (N. B. 1 and N. B. 4). The former, N. B. 3, was most common and was highly prized in the construction of native houses, fences, and as a



Fig. 1. Tassels which were not ready for harvest were brought back to headquarters on their stalks. These were kept living in a weak solution of sulfurous and phosphoric acids until the florets began to shatter. Photo by C. E. Pemberton.

soil binder along road fills. The light-tasseling and continuous-growing quality of this clon made it particularly attractive. In some sheltered areas (Fig. 2) straight, erect stalks 18 feet long were found which showed no cessation of growth. The seedlings derived from this clon are above average in growth and show a fair amount of variation in habit, although in general, they are heavy stoolers and semi-erect.

2. *The Islands of New Ireland and Lavongai:* These two islands lie to the north of New Britain. New Ireland is easily accessible for exploration because it has a road which runs 150 miles of its total length of 200 miles. Lavongai is workable only by boat or native trail.

The island of Lavongai is drained by innumerable rivers which are navigable by canoe for a mile or so inland, beyond which they break into rapids and wind through dense forest cover. The banks and mud flats bordering the lower reaches of all the rivers along the southern coast were covered with a single clon of *S. robustum*, which, curiously enough, was the same as found in native villages around Rabaul. This same clon (N. B. 3) was also found in many of the villages along



Fig. 2. Durability and continuous-growing ability of the stalks are some of the desirable characteristics furnished by *S. robustum*. The clon (N. B. 3) pictured above is also a light tasseler. Photo by C. E. Pemberton.

the New Ireland coast and in one isolated abandoned garden on the Lalet Plateau (elevation 2000 feet). The stalks of this clon are symmetrical, fibrous, and dry. They make the best building material of any of the *S. robustum* seen and this quality had apparently been recognized by the natives. A few stools of another variety (N. I. 1) were found on the Ungat River amid the usual run of N. B. 3. It is interesting to note that another isolated clump of the same clon was found also in a grass area some miles inland from the village of Lawun on New Ireland. How they arrived at these two widely separated and inaccessible places is interesting speculation.

New Ireland is a long narrow island with a backbone of limestone mountains rising to 3000 feet. Rain falling on the mountains disappears into underground channels and suddenly makes its appearance near the coast in the form of rushing torrents gushing from caves. In no case was cane observed growing wild along the banks of these rivers. Similar observations on the absence of wild cane in limestone country were made along the eastern coast of the Gazelle Peninsula.



Fig. 3. Large areas of *S. robustum* were found on the river flats of the Ramu Plateau (elevation 5500 feet). These thickets were made up of a population of many hundreds of varieties. Photo by C. E. Pemberton.

The search on these two islands yielded no new varieties of *S. robustum*. The native chewing canes were also conspicuously absent because the natives have long been under the influence of the white settlers and have learned to use the trade-store sugar.

3. *Plateau Country on New Guinea*: The island of New Guinea is approximately 1500 miles long by 400 miles wide, the surface almost entirely cut up with mountain ranges, some of which tower to over 15,000 feet.

Our objective on this island was to reach the large, open, grass plateau (elevation 5500 feet) at the headwaters of the Ramu River. We had assurance that the wild cane was in tassel. The Administrative Officers of the Territory of New Guinea made the trip possible by granting permission to enter this "uncontrolled area" and throwing open the facilities of the government outpost in this region. An airplane was used to cover the long distance into the interior, while native trails were used in searching the country within a fifteen-mile radius of the landing field. The climate on this plateau is nearly temperate although only three degrees south of the Equator.



Fig. 4. The grassy meadows of the Ramu Plateau (elevation 5500 feet) were populated with occasional clumps of what appeared to be an intermediate between *S. robustum* and *S. spontaneum*. Photo by C. E. Pemberton.



*S. robustum* was found flourishing on all the river flats and swampy ground of this plateau country. In some cases (Fig. 3) it would be massed in areas of 25 acres or more and growing in such a tangled mass that it was nearly impossible to penetrate. The natives select the interior of these *S. robustum* thickets to build their villages as the dense cane offers them a ready retreat in case of attack by neighboring tribes. These *S. robustum* thickets were made up of a population of hundreds of varieties, a situation quite different from that of the flats on the lowlands where apparently one or two clons dominated each of the rivers. Hours of examination revealed only occasional stalks with identical characteristics and these usually came from the same stool. Except for isolated clumps of *S. spontaneum* the population was primarily of the *S. robustum* species or what appeared to be intermediates between *S. spontaneum* and *S. robustum*.

Only occasional clumps of these intermediates (Fig. 4) were found on the grassy meadows above the wet river flats. Their continued existence in these locations was a precarious one because it is the custom of the natives to burn off the grasslands in dry weather in order to catch rodents upon which they depend for the meat

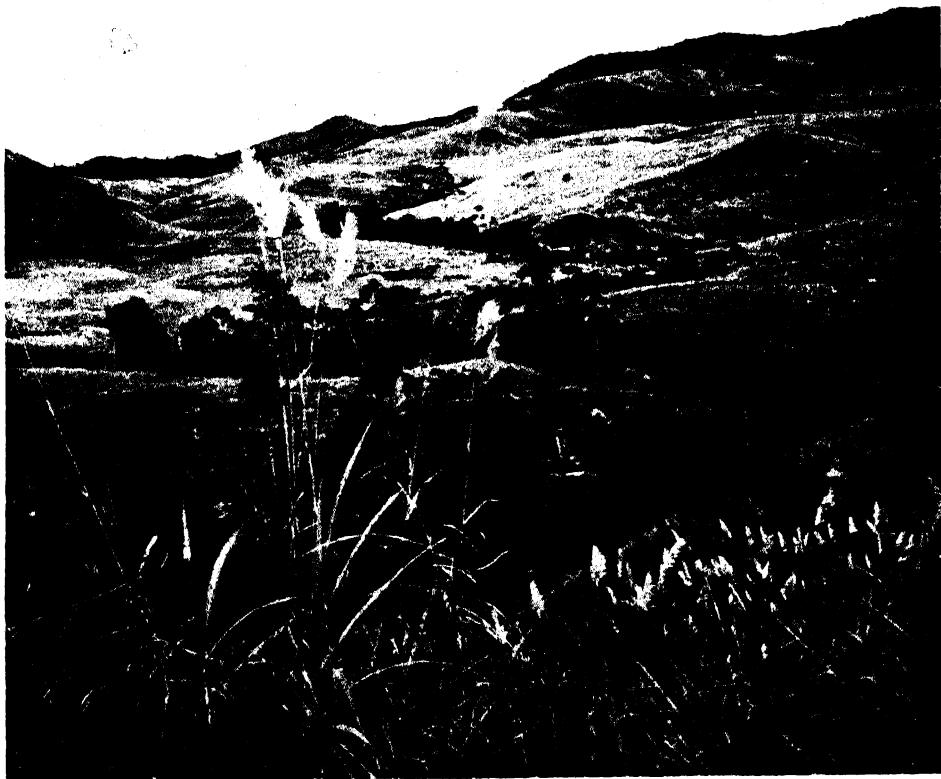


Fig. 5. *S. spontaneum* was the only species which grew on the dry ridges. It was found in considerable variation in random clumps throughout the plateau country.

portion of their diet. *S. spontaneum* (Fig. 5) was the only species which grew on the dry ridges. It was found in considerable variation in random clumps throughout the plateau country.

The seedlings derived from the collections made on this plateau country are among the most interesting in the quarantine field at present. They are extremely variable in growth habit giving us the full gamut from small-stalk, heavy-stooling types to types with sparse stooling and with rank-growing primaries. While in the greenhouse, many stalks of one of these crosses (Fig. 6) measured 17 feet from base to last visible leaf collar at the end of the six-month growing period. This was nearly twice the growth made by seedlings from fuzz collected on the lowlands.

The survey of the Ramu Plateau included a patrol over the divide and down into the headwaters of the Purari River, which drains into the Gulf of Papua. The wild cane pattern was much the same as that found on the other side of the divide. The natives, however, were more advanced agriculturally and their cultivated gardens were many acres in extent. Large gardens of sweet chewing canes of *S. officinarum* were found in each village.

Headquarters were moved to the town of Wau, the center of the gold mining district, after the completion of the survey of the plateau country. Here at an elevation of 2000 feet the Bulolo River winds through steep forested gorges. The occasional river flats were covered with a heavy growth of *S. robustum*. Variation in these *S. robustum* thickets was not as wide as was found on the plateau. Varieties of *S. spontaneum* were common on grassy clearings away from the river and intermediates between the two species were again found wherever moisture was sufficient. The seedlings from this region are characterized by heavy waxing of the

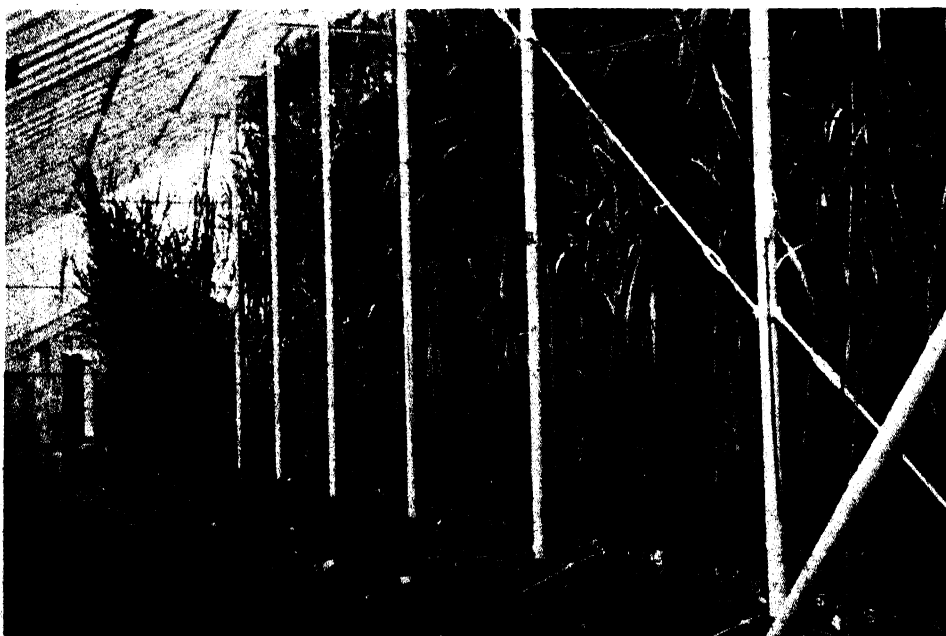


Fig. 6. The seedlings from some of the collections on the Ramu Plateau measured seventeen feet in length after six months' growth in the quarantine house. Each seedling was planted in a gallon fruit tin and received no fertilizer during this period. Photo by J. P. Martin.

stalks and long bristles solidly cover the leaf sheaths. In the quarantine field they show a high degree of variability from narrow-leaf types to broad-leaf types. A number have both surfaces of their leaves covered with a fine soft down.

4. *Coastal Rivers of Northern New Guinea*: The river banks and swamp areas of the lowlands are covered with dense thickets of wild cane. Here the terrain had not divided the *S. spontaneum* and *S. robustum* species as it had in the upper lands, for both were growing in confusion in these areas. The seedlings arising from these collections are on the whole above average, and show a high degree of variability in conformation and stooling habit. A number have unusually broad and thick leaves.

#### S. OFFICINARUM IN THE MANDATED TERRITORY OF NEW GUINEA

Sugar cane for chewing purposes is one of the essential components of the native's diet. No garden is complete without its few clumps of edible cane which are carefully tended. The native has selected in the direction of low fiber and softness with a result that most of the varieties would deteriorate quickly if allowed to lodge. To prevent this the native drives a stout pole alongside each stool and lashes the stalks to it. Usually 8 to 12 sticks are allowed to grow and these are kept free of trash.

The canes in every garden were carefully examined with the object of finding individuals which would be suitable for commercial conditions. Hand refractometer readings were made on all varieties which appeared to have any promise. In nearly all cases the canes were extremely soft and juicy, but the Brixes would only range from 10 to 15 in the mature section of the stalk. However, two varieties were found in the villages of the plateau country where the Brixes read between 20 and 22 and the conformation and hardness of stalk appeared quite suitable for commercial conditions. It was necessary to reject one of these because of Fiji disease, but cuttings of the other (N. G. 6) were taken.

Tasseling in these native gardens was something of rare occurrence and in only three cases were tassels found, and here it was noted that the natives followed the practice of breaking them off soon after their emergence. This might in part explain the total absence of any stools of cane which could have been construed as natural hybrids between *S. officinarum* and either *S. spontaneum* or *S. robustum*. Moreover, it is hardly likely that the natives would foster the growth of any such hybrids since they would be useful neither as chewing canes nor for building purposes.

#### EDIBLE TASSEL VARIETIES

A group of canes which fail to form normal tassels is common throughout New Guinea. Like the cauliflower this type produces an edible head of malformed, condensed flowers and branches that fail to emerge. On removal from the sheath it appears as a mealy mass. The natives use it as a vegetable, boiling or roasting it in its enclosing leaf sheath before eating. In all cases these varieties closely resembled *S. robustum* in all morphological characters. They are hardy, vigorous growers, and quite capable of competing with the jungle. The fewness of the clons lead one to believe that they may be mutants of *S. robustum* that were noticed by the natives

and propagated asexually. The distribution of edible tassel varieties extends from Fiji through New Guinea into the Dutch East Indies.

#### DISEASES OF SUGAR CANE OBSERVED

Fiji disease was found throughout the Territory of New Guinea. Symptoms of the disease could be found in nearly every native garden of varieties of *S. officinarum* from sea level to those in the plateau country at elevations of over 5500 feet. It was also found on numerous clumps of the edible tassel varieties along the coastal villages and in one case in the mountainous country of the gold region. Some of the varieties of *S. robustum* growing along rivers of the lowlands were also found carrying this disease. Downy mildew was noted on a few clumps of *S. spontaneum* growing along the headwaters of the Purari River (elevation 6000 feet).

None of the other diseases common to sugar cane were observed during this survey.

#### ACKNOWLEDGMENT

Every phase of the three months' work in this territory was materially assisted by the wholehearted cooperation of the Administrative Officials of the Territory of New Guinea, and particularly by G. H. Murray, Director of Agriculture, and his staff. We are also indebted to the many hospitable coconut planters and to others who supplied us in many ways with assistance.

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# An Annotated List of the Fungi and Bacteria Associated With Sugarcane and Its Products

By

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Caum<sup>2</sup> prepared and issued in 1921, under the auspices of the Hawaiian Sugar Planters' Association, "A contribution to a check-list of sugar cane fungi." This list served a useful purpose in bringing together accumulated information available at the time on the subject. During the seventeen years that have elapsed since the publication of Caum's list, many additions have been made from the several cane-sugar producing regions of the world and also many changes have been proposed in the nomenclature of previously recorded species, making a revision desirable.

In preparing this list Caum's plan has been followed in the main, with certain modifications and additions. The alphabetical plan is adhered to for ease of reference. Recognized species names are set in caps and small caps, synonyms in italics. Only those synonyms are cited which will be found in sugar-cane disease literature. Space limitations would not permit complete synonymy. The original place of publication is given for each accepted species name, together with the corresponding reference to Saccardo's *Sylloge Fungorum*. For the more important species a limited number of pertinent references have been included. The family to which each species belongs is recorded following the system of classification of Clements and Shear, *The Genera of Fungi*, 1931. Essential characters of the organism itself, together with its recorded geographical distribution, are given. The latter records relate, of course, only to the distribution insofar as reported on *Saccharum* spp.

The comprehensive works of Bell, Butler, Caum, Cook, Wakker and Went, and many others have been freely drawn on in compiling this account of sugarcane fungi and bacteria. The host index of the fungus literature of the world maintained by the Plant Disease Survey of the Bureau of Plant Industry, United States Department of Agriculture, constitutes an invaluable background from which the list has been prepared. However, no claim for completeness is made. Many species of bacteria, fungi, and yeasts reported, for example, in connection with the commercial fermentation industries are purposely omitted, the object being, in this instance, to record only the more extensively studied ones concerned in raw sugar deterioration and sugar-house sanitation.

No new names nor new combinations are proposed, although the work has revealed a number of the latter that might well be made for the sake of uniformity.

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<sup>2</sup>Bulletin III (Bot. Ser.) Part 1, pp. 66-97, 7 figs. 1921.

ACANTHORHYNCHUS LIGNORUM Shear, Bull. Torr. Bot. Club 24:313. 1907. Shear, Bur. Plant Ind. Bull. 110:26-30, pl. III (figs. 12-22). 1907. Sacc., Syll. Fungorum 22:300. 1913.

*Sphaeriaceae*. Perithecia subepidermal, long beaked, with septate paraphyses; asci 8-spored; spores 1-celled, brown, with gelatinous sheaths,  $24-32 \times 12-20 \mu$ . Reported on cane leaf in damp chamber. Barbados.

ACREMONIELLA ATRA (Cda.) Sacc. Syll. Fungorum 4:302. 1886. Ferraris, Flora Italica Crypt. Fasc. 6:268, fig. 76. 1910. Spegazzini, Rev. Agron. y Vet. 2:249. 1896. *Acremonium atrum* Cda., Icones Fung. 1:11, tab. III (fig. 168). 1837.

*Dematiaceae*. Forms a delicate white mycelial layer with dark, ovate-ellipsoid conidia,  $20-26 \times 16-20 \mu$ , borne singly on short erect conidiophores. On dead and dying leaves and culms. Argentina.

*Acremonium atrum* Cda. See *Acremoniella atra* (Cda.) Sacc.

ACROSTALAGMUS ALBUS Preuss, Linnaea 24:126. 1851. Sacc., Syll. Fungorum 4:163. 1886. Spegazzini, Rev. Agron. y Vet. 2:247. 1896.

*Moniliaceae*. Reported by Spegazzini as the conidial stage of *Melanospora globosa* Berl. (q. v.) developed in cultures, but not found on cane in the field. The conidial size given ( $9-12 \times 2.5-4 \mu$ ) is much larger than the original description calls for ( $3.4 \times 1-1.5 \mu$ ). Argentina.

ACROSTALAGMUS ALBUS Preuss var. DICHOTOMA Speg., Anal. Mus. Nac. Buenos Aires 6:333. 1899. Sacc., Syll. Fungorum 16:1037. 1902.

*Moniliaceae*. White mold on heaps of decaying leaves. Conidia capitate, continuous or 1-septate, hyaline, fusoid or ovate,  $10-16 \times 4-6 \mu$ . Argentina.

ACROSTALAGMUS CINNABARINUS Cda., Icones Fung. 2:15, pl. 10 (fig. 66). 1838. Sacc., Syll. Fungorum 4:163. 1886. Spegazzini, Rev. Fac. Agron. y Vet. 2:247. 1896.

*Moniliaceae*. Powdery, cinnabar colored conidial masses; conidia borne in globose heads on hyaline verticillately branched conidiophores,  $3-4 \times 1.5 \mu$ . On rotten leaves, culms and other debris. Puerto Rico and doubtless in all cane-growing regions.

ACROSTALAGMUS GLAUCUS Fawcett, Rev. Ind. y Agric. Tucuman 13:45, 1 fig. 1922.

*Moniliaceae*. Conidia agglomerated in heads, ovate-ellipsoid, hyaline,  $4-5 \times 2.5-3 \mu$ . Commonly present in rotting canes. Argentina.

ACROSTALAGMUS SACCHARI Fawcett, Rev. Ind. y Agric. Tucuman 13:45, 1 fig. 1922.

*Moniliaceae*. Conidia in heads, ovoid or oblong-ellipsoid, hyaline,  $3.5-4 \times 2-2.5 \mu$ . An active agent in rotting canes left after harvesting. Argentina.

*Acrothecium* sp. See *Curvularia*

*Acrothecium lunatum* Wakker See *Curvularia lunata* (Wakker) Boedijn

ACTINOMYCES sp.

*Actinomycetaceae*. Isolated from canes attacked by top rot. Uganda. Not considered causative.

*AEROBACTER AËROGENES* (Kruse) Beijerinck, Centralbl. f. Bakt. Abt. II, 6:193. 1900.

*Bacteriaceae*. A widely distributed saprophyte found by Wolzogen Kühr associated with normal and Seréh-diseased cane. Java.

*ALLANTOSPORA RADICICOLA* Wakker, Arch. v. Java Suikerind. 4:892-6, pl. 19. 1896. Wakker and Went, De Ziekten van het Suikerriet op Java, pp. 179-183, 194, pl. 24. 1898. Sacc., Syll. Fungorum 14:1043. 1899.

*Moniliaceae*. Conidiophores erect, septate; conidia 1-2 septate, allantoid,  $10-28 \times 4 \mu$ , capitate. Reported as parasitic on young cane roots in Java, and "a general cane saprophyte" in Hawaii. Possibly occurs in Surinam.

*Allantospora sacchari* ex Cooke, Proc. Int. Soc. Sugar Cane Tech. (4) Bull. 128:4. 1932. *Nomen nudum*.

*ALTERNARIA TENUIS* Nees, Syst. der Pilze u. Schwämme, p. 82, fig. 68, 1817. Sacc., Syll. Fungorum 4:545. 1886. Spegazzini, Rev. Agron. y Vet. 2:252. 1896. Mason, Annotated Account Fungi Received at Imper. Bur. Myc. II (fasc. 1), pp. 20-22. 1928.

*Dematiaceae*. Conidia single or in chains, long beaked, muriform, dark,  $20-50 \times 10-15 \mu$  (average), but variable. A group of forms or a species complex. Greenish brown to black mold as a common saprophyte on dead and dying leaves and canes, Puerto Rico, Argentina, India, and doubtless in all cane regions. *Alternaria* sp. isolated from roots, Louisiana, "but probably of no significance in root disease complex."

*Amoebosporus saccharinum* Cook See *Plasmodiophora vascularum* Matz

*Amoebosporus vascularum* Cook See *Plasmodiophora vascularum* Matz

*Anthostomella paraguayensis* Speg. See *Rosellinia paraguayensis* Speg.

*APIOSPORA CAMTOSPORA* Penz. and Sacc., Malpighia 11:398. 1897. Sacc., Syll. Fungorum 14:534. 1899. Penzig and Sacc., Icones Fung. Javanicorum, p. 12, pl. 9 (fig. 4). 1904. Theissen and Syd., Ann. Myc. 13:421. 1915.

*Dothideaceae*. Black, linear stromata, 1 mm long, subepidermal; asci 8-spored; spores  $35-38 \times 9-10 \mu$ .

On dead and dying leaves. Philippine Islands, Java, Burma. Clements and Shear, Genera of Fungi, consider *Apiospora* synonymous with *Scirrhia*.

*APOSPHAERIA* (?) *BERGII* Speg., Rev. Agron. y Vet. 2:240. 1896. Sacc., Syll. Fungorum 14:894. 1899.

*Phomaceae*. Numerous black, membranous, superficial pycnidia; conidia ellipsoid,  $5-7 \times 3 \mu$ . Produces indefinite yellow areas on young unfolding leaves. Argentina.

*ARCYRIA CINEREA* (Bull.) Pers., Syn. Meth. Fung., p. 184. 1801. Macbride and Martin, The Myxomycetes, p. 271, pl. XVII. 1934.

*Arcyriaceae*. Sporangia stipitate, gray; stipes 0.2-2 mm long; spores hyaline, 6-8  $\mu$ . On cane trash. Puerto Rico, Java.

*ARCYRIA DENUDATA* (L.) Wettstein, Verh. Zool.-Bot. Ges. Wien 36:585. 1886. Macbride and Martin, The Myxomycetes, p. 273, pl. XVIII. 1934.

*Arcyriaceae*. Sporangia stipitate, crimson, weathering to reddish brown or brown; spores red in mass, 6-8  $\mu$ . On cane trash. Puerto Rico.

# ARMILLARIA sp.

*Agaricaceae*. Typical black rhizomorphs produced beneath lower leaf sheaths. Associated with the root disease complex. Tanganyika. See *A. mellea*.

**ARMILLARIA MELLEA** (Vahl) Fr., Syst. Myc., p. 30. 1821. Sacc., Syll. Fungorum 5:80. 1887. Wallace, E. Afric. Agric. Jour. 1:183. 1935.

*Agaricaceae*. Pileus 3-10 cm broad, oval to subhemispherical, finally plane, normally honey-colored, but varying to yellowish-brown or rusty brown; gills adnate or decurrent, yellowish; stipe 5-15 cm long; veil well developed; spores elliptical-ovate, hyaline, smooth,  $8-9.5 \times 5-6.5 \mu$ . Associated with root disease. Tanganyika.

**ARTHOBOTRYS SUPERBA** Cda., Prachtfl. p. 43, pl. XXI. 1839. Sacc., Syll. Fungorum 4:181. 1886. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:222, pl. XXX (figs. 7-9). 1917.

*Moniliaceae*. Forms a white to pinkish mold; conidiophores inflated at septa; conidia borne in clusters at the septa, 1-septate, hyaline,  $15-30 \times 8-15 \mu$ . On dead and dying leaves and stalks. Puerto Rico, Argentina.

**ARTHRIINIUM SACCHARICOLA** Stevenson, Jour. Dept. Agric. P. Rico 1:223, pl. XXIX (figs. 1-3). 1917. Sacc., Syll. Fungorum 25:771. 1931.

*Dematiaceae*. Small black masses on dead leaf blades; fertile hyphae erect, with numerous thick dark septae; conidia sessile, borne spirally around conidiophores,  $7-8 \times 4-5 \mu$ . Puerto Rico.

# ASPERGILLUS

In addition to the species discussed hereafter, various unnamed forms have been reported by pathologists and others working on sugar deterioration, root rot, and other cane problems, Louisiana, Hawaii, Puerto Rico. Following Thom and Church (*The Aspergilli*) and other workers, *Aspergillus* is used rather than *Eurotium* for these fungi.

**ASPERGILLUS ARGENTINUS** Speg., Rev. Agron. y Vet. 2:245, 1896. Sacc., Syll. Fungorum 14:1046. 1899. *Eurotium argentinum* Speg., Rev. Agron. y Vet. 2:228. 1896. Sacc., Syll. Fungorum 14:463. 1899. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:212. 1917.

*Moniliaceae*. Gray mold on cut cane leaves and cane trash. Argentina, Puerto Rico. Perithecia yellow, 50-80  $\mu$  in diameter; spores hyaline, globose or ellipsoid,  $4-5 \times 3-4 \mu$ . Thom and Church (*The Aspergilli*, p. 116. 1926) state "this form apparently belongs in the *A. glaucus* group, but since characters listed are insufficient to identify, the name should be deleted unless rediscovered."

**ASPERGILLUS CANDIDUS** Lk., Observationes I, p. 14. 1809. Sacc., Syll. Fungorum 4:66. 1886. Spegazzini, Rev. Agron. y Vet. 2:246. 1896. Thom and Church, *The Aspergilli*, p. 157. 1926.

*Moniliaceae*. White mold on dead cane leaves. Argentina. (*A. candidus* group of Thom and Church).



ASPERGILLUS FLAVIPES (Bainier and Sartory) Thom and Church, The Aspergilli, p. 155. 1926. *Sterigmatocystis flavipes* Bainier and Sartory, Bull. Soc. Myc. France 27:90-96, pl. III (figs. 1-6). 1911.

*Moniliaceae*. Heads white, stalk walls yellow. A mold on sugar products. Louisiana. (*A. flavipes* group of Thom and Church).

ASPERGILLUS FLAVUS Lk., Observationes I, p. 16. 1809. Sacc., Syll. Fungorum 4:69. 1886. Thom and Church, The Aspergilli, pp. 203-7. 1926.

*Moniliaceae*. *Flavus-oryzae* (yellow-green) group. On dead leaves and leaf sheaths, Egypt, Puerto Rico; on baled bagasse, Louisiana; and on sugar, Java, Louisiana. A form (*A. parasiticus* Speare, Hawaiian Sugar Planters' Exp. Sta. Path. Ser. Bull. 12:38. 1912) on cane mealy bugs. Hawaii, Puerto Rico, Demerara.

ASPERGILLUS FUMIGATUS Fres., Beitr. z. Myk., p. 8, pl. 10 (figs. 1-11). 1850-3. Sacc., Syll. Fungorum 4:65. 1886. Thom and Church, The Aspergilli, pp. 128-9. 1926.

*Moniliaceae*. *Aspergillus fumigatus* group. Colonies green to dark green or nearly black; conidiophores up to  $300 \times 2.8 \mu$ ; sterigmata in one series; conidia dark green in mass, globose,  $2.3\text{--}3.5 \mu$ . On sugar and piles of bagasse. Louisiana.

ASPERGILLUS HERBARIORUM (Wiggers) Fischer in Engler and Prantl, Die Naturl. Pflanzenf. Teil 1, Abt. 1, p. 301. 1896. Thom and Church, The Aspergilli, p. 106. 1926. *Eurotium herbariorum* Lk., Observationes, p. 31, pl. 2 (fig. 44). 1809. Sacc., Syll. Fungorum 1:26. 1882.

*Moniliaceae*. *Aspergillus glaucus* group. Conidia ashy green to olive and greenish-black in age, oval to elliptical,  $6.5\text{--}7.5 \times 9.5\text{--}11 \mu$ . Sulphur-yellow, globular perithecia; ascospores with furrows and crests,  $6.6\text{--}9.6 \times 5.8\text{--}7.5 \mu$ . Common on dead leaves and other cane debris, particularly on herbarium specimens. Puerto Rico and probably general.

ASPERGILLUS NIDULANS (Eidam) Wint., in Rabh. Krypt. Flora 2 Aufl., Bd. 1, Abt. 11:62. 1887. Thom and Church, The Aspergilli, pp. 137-9. 1926.

*Moniliaceae*. *A. nidulans* group. Colonies white to yellowish-green; conidiophores more or less flexuous, cinnamon brown,  $50\text{--}200 \times 3\text{--}5 \mu$ , with primary and secondary sterigmata; conidia globose, greenish, smooth or rough,  $3\text{--}4 \mu$ ; perithecia globose,  $200\text{--}300 \mu$  diam.; ascospores purple-red, with equatorial band,  $4 \times 5 \mu$  (average). On sugar. Louisiana.

ASPERGILLUS NIGER v. Tiegh., Ann. Sci. Nat. Bot. ser. 5, 8:240. 1867. Thom and Church, The Aspergilli, pp. 167-170. 1926. *Sterigmatocystis niger* v. Tiegh., Bull. Soc. Bot. France 24:102-103. 1877. Sacc., Syll. Fungorum 4:75. 1886.

*Moniliaceae*. Heads purple brown to black; conidia globose or subglobose. On dead cane stalks and leaves. Puerto Rico, Java. On piles of bagasse and as an agent in sugar deterioration. Louisiana.

ASPERGILLUS PENICILLIOIDES Speg., Rev. Agron. y Vet. 2:246. 1896. Sacc., Syll. Fungorum 14:1045. 1899. Thom and Church, The Aspergilli, p. 126. 1926.

*Moniliaceae*. Heads dusky green, no perithecia noted. An intermediate form between *A. glaucus* and the *A. fumigatus* group (Thom and Church).

Conidia ellipsoid,  $3-4 \times 2.5 \mu$ . On moldy cane, Argentina, and causing mold of sugar products, Louisiana.

*ASPERGILLUS REPENS* (Cda.) deBy. and Wor., Beitr. z. Morph. u. Phys. der Pilze, p. 379. 1866. Sacc., Syll. Fungorum 4:64. 1886. Thom and Church, The Aspergilli, p. 113-114. 1926.

*Moniliaceae*. *A. glaucus* group. Conidia globose or oval, verruculose,  $4-8.5 \mu$ ; perithecia yellow, minute; spores hyaline, without ridges or furrows,  $4-7 \times 3.7 \mu$ . On sugar. Louisiana.

*ASPERGILLUS SACCHARI* Speg., Anal. Mus. Nac. Buenos Aires 6 (ser. 2<sup>a</sup>, vol. 3): 244. 1899. *Eurotium sacchari* Speg., Loc. cit.

*Moniliaceae*. Sulphur yellow perithecia,  $150 \mu$  in diam.; ascospores ellipsoid, hyaline,  $4-6 \times 2-4 \mu$ . "Lacks essential characters necessary to separate it from other forms of *A. glaucus* with yellow perithecia." Thom and Church, The Aspergilli, p. 115. 1926. Argentina.

*ASPERGILLUS SYDOWI* (Bainier and Sartory) Thom and Church, The Aspergilli, pp. 147-8. 1926. *Sterigmatocystis sydowi* Bainier and Sartory, Ann. Myc. 11:25-29, pl. III. 1913. Sacc., Syll. Fungorum 25:663. 1931. (Referred to *A. nidulans* (Eidam) Wint.).

*Moniliaceae*. *Aspergillus versicolor* group. Forming a velvety, blue-green mold on sugar. Louisiana, Union So. Africa.

*ASPERGILLUS TERREUS* Thom, in Svensk Bot. Tids. 10:5. 1916. Thom and Church, Amer. Jour. Bot. 5:85-6. 1918. Thom and Church, The Aspergilli, pp. 150-2, 1 fig. 1926. Sacc., Syll. Fungorum 25:659. 1931.

*Moniliaceae*. Colonies cinnamon to deeper brown in age; conidiophores  $50-150 \mu$  long,  $5-8 \mu$  diam., flexuous; sterigmata in two series; conidia elliptical to globose, smooth, in long chains,  $2.2-2.5 \mu$  diam., perithecia not found. On baled bagasse. Louisiana.

*ASPERGILLUS VARIANS* Wehm., Bot. Centralbl. 80:460. 1898. Sacc., Syll. Fungorum 16:1028. 1902. Thom and Church, The Aspergilli, p. 127. 1926.

*Moniliaceae*. An *Aspergillus* "of doubtful relationships," on sugar solutions. Germany.

*Asterina concentrica* Cke. See *Asterula concentrica* (Cke.) Sacc.

*Asterostroma albido-carneum* Mass. See *Asterostroma cervicolor* (Berk. and Curt.) Mass.

*ASTEROSTROMA CERVICOLOR* (Berk. and Curt.) Mass., Linn. Soc. Bot. Jour. 25:155. 1889. Sacc., Syll. Fungorum 9:237. 1891. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:215, pl. XXVI (figs. 4-7). 1917. Bourdot and Galzin, Bull. Soc. Myc. Fr. 36:44. 1920. *Asterostroma albido-carneum* Mass., Linn. Soc. Bot. Jour. 25:135, pl. 46 (figs. 8, 9). 1889.

*Thelephoraceae*. Thin, effused, spongy, dry fungus layer formed on dead leaf-sheaths at base of living stalks and on surrounding soil and trash. Characteristic stellate organs in hymenium; cystidia present; spores hyaline, spherical, echinulate,  $4-5 \mu$  in diam. Puerto Rico.

ASTERULA CONCENTRICA (Cke.) Sacc., Syll. Fungorum 9:377. 1891. *Asterina concentrica* Cke., Grevillea 14:13. 1885.

*Perisporiaceae*. Dark brown, orbicular, then confluent spots on culms; spores elliptical, continuous (?), hyaline,  $8 \times 3 \mu$ . N. W. India. Theissen (Ann. Myc. 10:13. 1912) deletes the species saying, "eine unreife Dothideaceae." The genus *Asterula* is no longer recognized.

BACILLUS ANANAS Serrano, Phil. Jour. Sci. 36:271-300, pls. 1-19. 1928. *Erwinia ananas* Serrano, L. c.

*Bacteriaceae*. This organism, reported as the cause of a brown rot of pineapple fruitlets, was found by inoculations to cause red streaks in cane stalks. Philippine Islands.

BACILLUS FLAVIDUS Fawcett, Rev. Ind. y Agric. Tucuman 13:5-15. 1922. Review App. Myc. 2:338. 1923.

*Bacteriaceae*. Organism motile, flagellate, no spores, gram negative, associated with top rot or "polvillo." Affected canes show reddish stains on upper sheath, red streaks on leaves, terminal bud rots with production of an evil smelling liquid. Forms tentatively called *Bacillus* D and *Bacillus* F also associated. Argentina. See also *Bacillus sacchari* Speg. Fawcett's use of the name is untenable, it having been applied by Morse (Jour. Inf. Diseases 11:284. 1912) to a pathogenic organism isolated from the nose and throat of animals. Bolle (Arch. Suikerindus. Ned.-Indië 1927, p. 593) believes that polvillo is pokkah boeng or top rot.

BACILLUS GLAGAE Janse, Meded., 's Lands Plant. 9:1-56, figs. 11-16. 1891.

*Bacteriaceae*. An organism said to have been associated with Seréh, but also reported as occurring on *Saccharum spontaneum* and other hosts, so doubtless a normal inhabitant of cane. Java.

BACILLUS LEVANIFORMANS Grieg-Smith, Proc. Linn. Soc. N. So. Wales 26:614, pl. 30. 1901.

*Bacteriaceae*. Organism aerobic, rod-shaped,  $1.3-2 \times 1-6 \mu$ , gram positive, found in connection with studies on sugar deterioration. New South Wales.

BACILLUS LIODERMOS (Flügge) Chester, Man. Det. Bacter., p. 272. 1901.

*Bacteriaceae*. Concerned with raw sugar deterioration. Louisiana.

BACILLUS MEGATHERIUM DeBary, Vergl. Morph. u. Biol. der Pilze, Mycetozoa u. Bacteria, p. 499, fig. 194. 1884.

*Bacteriaceae*. A common soil organism found associated with normal and Seréh-diseased cane (Kühr), which when inoculated produced red discolorations, but not Seréh. Also associated with sugar deterioration. Louisiana.

BACILLUS MESENTERICUS (Flügge) Migula, Syst. der Bakterien 2:555-6. 1900.

*Bacteriaceae*. Associated with sugar deterioration, including var. *ruber*, *fuscus*, *niger*, and *vulgatus*. Louisiana. See also statement under *Bacillus megatherium*.

BACILLUS POLYMYXA (Praz.) Gruber, Centbl. Bakt. II Abt. 14:353. 1905.

*Bacteriaceae*. Isolated from normal cane stalks by Wolzogen Kühr. Java.

**BACILLUS PSEUDARABINUS** Grieg-Smith, Proc. Linn. Soc. N. So. Wales 29:453. 1904.

*Bacteriaceae*. Organism a short, thick rod with rounded ends, flagellate, non-spore forming, found associated with internal red stripes in stalks. New South Wales. *Red string of sugar cane*.

**BACILLUS SACCHARALIS** Owen, Jour. Bact. 1:239, 3 figs. 1916.

*Bacteriaceae*. Organism a short thick rod, with rounded ends, gram positive,  $2.8 \times 1.0 \mu$ , non-motile, non-flagellate, non-spore forming. Found in moth stalk-borer galleries and considered an agent in cane deterioration. Louisiana.

**BACILLUS (?) SACCHARI** Janse, Mededeel. 's Lands Plant. 9:1-56, figs. 1-10. 1891. Rev. Bot. Centbl. 40:374. 1892. Smith, Bacteria in Relation to Plant Diseases 3:72-80. 1914.

*Bacteriaceae*. Organism an aerobic spore former, said to be a contributory cause of Seréh in Java, but since found in many other plants as well as cane, probably a normal inhabitant of these plants and not pathogenic. Went suggests the organism is *B. subtilis*. A *Bacillus sacchari*, not further identified, associated with sugar deterioration. Louisiana.

**BACILLUS SACCHARI** Speg., La Gangrena Humeda ó Polvillo de la Caña de Azucar en Tucuman, p. 23. 1895. Spegazzini, Rev. Fac. Agron. y Vet. 2:238. 1896. Smith, Bacteria in Relation to Plant Diseases 3:85-88. 1914.

*Bacteriaceae*. Organism described as chromogenic (red), aerobic, solitary or in chains,  $1.5-3 \times 0.8 \mu$ . Found associated with top rot (gangrena humeda). Argentina. Smith (l. c.) states that "it is an open question whether the disease is or is not Cobb's disease." Elliott refers the species to *Bacterium vasculorum* (Bacterial Plant Pathogenes, p. 253. 1930.) See *Bacillus flavidus* Fawcett, which may well be the same organism, since apparently the same disease is involved.

**BACILLUS SACCHARI** Roldan, Phil. Agric. 20:247-258, 5 pls. 1931. *Erwinia sacchari* Roldan, l. c.

*Bacteriaceae*. Organism a cylindrical rod with rounded ends, occurring singly or in pairs, motile by 4 to several peritrichiate flagella, non-spore forming, gram negative,  $0.9-2.2 \times 0.5-0.7 \mu$ . Causes a soft top rot with unpleasant odor. Philippine Islands. The name is untenable, having been used at least twice previously (q. v.) and the present organism should be renamed if it is to remain in the genus *Bacillus*. *Bacterial stem rot*.

**BACILLUS SUBTILIS** (Ehrbg.) Cohn, Beitr. z. Biol. d. Pflanzen 1:175. 1872.

*Bacteriaceae*. A common soil organism found in connection with pokkah-boeng, and isolated from normal and Seréh-diseased cane. Saprophytic. Java.

*Bacillus vascularum* Cobb See *Bacterium vasculorum* (Cobb) Grieg-Smith

**BACILLUS VULGATUS** Trevisan, I Gen. e Spec. d. Batteriacee, p. 19. 1889. *Bacillus mesentericus vulgatus* Flügge, Die Mikroorganismen, p. 322. 1886.

*Bacteriaceae*. Concerned with raw sugar deterioration. Louisiana.

## BACTERIUM spp.

Bacteria not specifically named have been reported found in cases of top rot. British Guiana, Louisiana.

BACTERIUM ALBILINEANS Ashby, Trop. Agric. 6:138. 1929. Wilbrink, Arch. Suikerindus. Ned.-Indië 28:1399-1525. 1920. North, Colon. Sugar Refining Co., Agric. Rept. 8, 80 pp., 2 col. pls., 1926; also No. 9, 48 pp., 2 col. pls., 1929. Martin, Carpenter and Weller, Hawaiian Pl. Rec. 36:145-196, 23 figs., 1 col. pl. 1932.

*Bacteriaceae*. Organism motile by single polar flagellum, slender, .2-.3  $\mu$  diam.; producing long white stripes of uniform width on leaf-blades with rose colored vascular bundles in nodes and buds. In acute cases plants wilt; in chronic form stools are dwarfed with side shoot development, leaves chlorotic. A vascular disease without gum production. Australia, Fiji, Formosa, Japan, Java, Hawaii, Madagascar, Mauritius, Philippine Islands, Reunion.

*Leaf Scald, Java gum disease, Gomziekte.*

BACTERIUM ANDROPOGONI E. F. Smith, Bact. Relation Pl. Dis. 2:63. 1911. Elliott and Smith, Jour. Agric. Res. 38:1-22. 1929.

*Bacteriaceae*. Produced red stripes on cane leaves where inoculated. United States.

BACTERIUM FLUORESCENS LIQUEFACIENS (Flügge) Lehm. and Neumann, Atl. Prin. Bact. 2:285. 1901.

*Bacteriaceae*. Found in reddened cane tissues, associated with *Bacillus pseudarabius* Grieg-Smith. New South Wales. Isolated from Seréh-diseased cane, Java.

BACTERIUM HERBICOLA AUREUM Burri and Duggeli, Centbl. f. Bakt. 13:56-63, 198-200. 1904. Wolzogen Kühr, Arch. Suikerind. Ned.-Indië 31:321-484. 1923.

*Bacteriaceae*. Organism isolated from normal and Seréh-diseased plants. Java.

BACTERIUM HERBICOLA VASCULARUM Wolzogen Kühr ex van Hall, Med. v. het Lab. voor Plantenz. 36:45. 1919.

*Bacteriaceae*. Reported to van Hall (l. c.) by director of Proefsta. Java Suikerindus. as associated with Seréh and as the cause of Java gum disease (leaf scald). Statements based on work of Wolzogen Kühr, although subsequent paper by latter uses only the preceding trinomial. Apparently a temporary name.

BACTERIUM PRODIGIOSUM (Ehrenberg) Lehm. and Neum., Determinative Bact. 2:458. 1931.

*Bacteriaceae*. Isolated from Seréh-diseased cane (Wolzogen Kühr), saprophytic. Java.

BACTERIUM PYOCYANEUM SACCHARUM Desai, Indian Jour. Agric. Sci. 5:387-391. 1935.

*Bacteriaceae*. Organism gram negative, non-spore forming, 1-flagellate (polar), not acid fast; colonies bluish. Affected canes wilt with production

of peculiar fermenting odor; tissues ferment and disintegrate from bud to root, entire cane becoming a mass of soft evil-smelling pulp. India.

*Stinking rot.*

**BACTERIUM RUBRILINEANS** (Lee, Purdy, Barnum, and Martin) Elliott, Manual Bact. Plant Pathogens, p. 195. 1930. *Phytomonas rubrilineans* Lee, Purdy, Barnum, Martin, Red-Stripe Disease Studies Exp. Sta. Hawaiian Sugar Pl. Assoc., p. 72. 1925. Bolle, Arch. Suikerindus. Ned.-Indië 1929:1147-1218, 5 pl. (1 col.). 1929. Cottrell-Dormer, Queensland Bur. Sugar Exp. Sta. Path. Bull. 3, 35 pp., 1 col. pl. 1932.

*Bacteriaceae.* Organism a short cylindrical rod, 1-3 polar flagellate, motile, gram negative,  $1.6 \times .7 \mu$ ; producing long narrow, bright red streaks 15-40 cm long  $\times$  .5-2 mm wide, on leaves and leaf-sheaths, and top rot when severe.

*Red-stripe "Polvillo" (?)*

Argentina, Brazil, Cuba, Dutch East Indies, Formosa, Hawaii, India, Indo-China, Kenya, Philippine Islands, Puerto Rico, Queensland, United States, Uganda.

[**PHYTOMONAS**] **RUBRISUBALBICANS** Christopher and Edgerton, Jour. Agric. Res. 4:259-267, 2 figs. 1930. Cottrell-Dormer, Queensland Bur. Sugar Exp. Sta. Path. Bull. 3:56-57, 1 col. pl. 1932.

*Bacteriaceae.* Organism a short rod, motile, with polar flagella, gram negative, non-spore forming, causing red stripes with white background, which may coalesce to give a mottled effect. Stripes up to a meter in length, few to many.

*Mottled-stripe.*

Louisiana, Puerto Rico, Queensland. The binomial is cited as published to avoid making a new combination.

**BACTERIUM SACCHARI** Grieg-Smith, Proc. Linn. Soc. New So. Wales 27:142-3, 1 pl. 1902.

*Bacteriaceae.* Organism a short rod with rounded ends, occurring singly or in pairs, motile, 1-9 flagellate,  $1-2 \times .6 \mu$ . Apparently an inhabitant of normal as well as diseased cane found when studying *Bacterium vasculorum* (Cobb) Grieg-Smith. The *Bacterium sacchari* Janse mentioned by Wakker and Went (l. c., p. 90) evidently refers to *Bacillus sacchari* Janse.

**BACTERIUM VASCULORUM** (Cobb) Grieg-Smith, Proc. Linn. Soc. New So. Wales 27:31-47, 2 pls. 1902. Ashby, Trop. Agric. 6:135-8. 1929. North, Colon. Sugar Ref. Co. Agric. Rept. 10, 150 pp., 7 figs., 2 col. pls. 1935. *Bacillus vascularum* Cobb, Agric. Gaz. New So. Wales 4:777-98, 14 figs. 1893. *Pseudomonas vascularum* (Cobb) E. F. Smith, U. S. Dept. Agric. Div. Veg. Phys. and Path. Bull. 28:153. 1901. *Phytomonas vascularum* (Cobb) Bergey et al, Man. Deter. Bact. ed 3, p. 247. 1930.

*Bacteriaceae.* Organism yellow, a short rod, motile, 1-flagellate, non-spore forming,  $.6-1.5 \times .3-.5 \mu$ ; producing a vascular disease marked by dwarfing, etiolation, red stripes on leaves, decay of terminal buds, and with yellow slime or gum produced in the bundles.

*Gumming disease, Cobb's disease, Gummosis.*

Antigua, Barbados, Brazil, Colombia, Dominica, Fiji, Guadeloupe, Madeira, Mauritius, Mexico (?), New Guinea, New South Wales, Puerto Rico, Queens-

land, Reunion, St. Kitts, St. Lucia. Ashby (Trop. Agric. 6:135-8, 1929) indicates existence of two strains of this organism. Kirchner (Zeit. Pflanzenkr. 34:260, 1924) points out that the species name should be spelled "vascularum."

Puncture inoculations of *Holcus sorghum* gave gumming leaf symptoms, and on sweet corn produced symptoms similar to those induced on this host by *Aplanobacter stewarti* (E. F. Smith) McCulloch (Ivanoff, Phytopath. 25:21, 1935). Gumming was transmitted to certain varieties of corn under natural conditions. Queensland (Ann. Rept. Bur. Sugar Exp. Sta's in 1935, p. 26, 1936).

BACTERIUM VULGARE (Hans.) Lehm. and Neum., Determinative Bact. 2:485. 1931.

*Bacteriaceae*. Isolated from Seréh-diseased cane (Wolzogen Kühr). Java.

BAKEROPIHOMA SACCHARI Died., Ann. Myc. 14:63. 1916. Sacc., Syll. Fungorum 25:182. 1931.

*Phomaceae*. Produces small reddish spots at base of leaf blade and upper portions of sheath, 1-4 mm in length, with white centers and red borders. Conidia ellipsoid,  $4-5 \times 2.5 \mu$ . China, Philippine Islands. The genus is reduced to synonymy with *Phoma* by Clements and Shear.

*Baker's leaf spot.*

*Basisporium gallarum* Moll. See *Nigrospora oryzae* (B. and Br.) Petch

BOTRYODIPLODIA SACCHARINA Died., Ann. Myc. 14:203. 1916. Sacc., Syll. Fungorum 25:313. 1931.

*Phomaceae*. Conidia 2-celled, brown, ellipsoid, not constricted at the septa,  $24-28 \times 10-15 \mu$ . On dead culms. India. Probably not distinct from *Diplodia cacaicola* P. Henn. See *Physalospora rhodina* (Berk. and Curt.) Cke.

*Dry rot.*

*Botryodiplodia theobromae* Pat. See *Physalospora rhodina* (Berk. and Curt.) Cke.

BOTRYTIS sp.

*Moniliaceae*. Gray mold on dead leaves. Puerto Rico.

[BROWN ROT] Wood, Queensland Agric. Jour. 29:197. 1928.

*Undetermined*. Dark brown felt-like fungus layers formed between outer leaf sheaths, which are cemented together and rotted. Stalks internally dry, pithy and soon dying. Queensland.

CALONECTRIA GIGASPOA Mass., Kew. Bull. Misc. Inform. 1906-257. 1906. Sacc., Syll. Fungorum 22:490. 1913.

*Hypocreaceae*. A saprophyte found in moth stalk-borer galleries; spores hyaline, subfusoid, triseptate,  $90-100 \times 20 \mu$ . Trinidad.

CAPNODIUM spp.

*Capnodiaceae*. Form black sooty fungus layers on leaves and stalks following mealybugs, leafhoppers, and other insects. None have been named specifically, only imperfect fruiting stages being present, *Triposporium*, *Fumago*, *Coniothecium*, *Cladosporium*, etc. The finding of perfect stages will permit specific assignments in *Capnodium* or its many segregates. All saprophytic, a

Brazilian report to the contrary, doubtless in error. Sooty molds have been referred at times, but erroneously, to *Meliola*.

*Sooty mold, black smut, fumagine, etc.*

Argentina, Brazil, British Guiana, Hawaii, India, Java, Mauritius, New South Wales, Philippine Islands, Puerto Rico, Queensland, South China.

CATENULARIA ECHINATA Wakker in Wakker and Went, Ziekt. v. h. Suikerriet op Java, p. 196. 1898. Sacc., Syll. Fungorum 14:1076. 1899.

*Dematiaceae*. Conidia dark, globose, in chains,  $14\ \mu$  diam. On dead stalks. Java. "This may be a form of *Sphaeronema adiposum*" Caum.

CEPHALOSPORIUM spp.

*Moniliaceae*. Unnamed forms associated with root disease (Louisiana), top rot (Uganda) and a "new disease" (Barbados). The latter probably *C. sacchari* (q. v.).

CEPHALOSPORIUM SACCHARI Butler, Mem. Dept. Agric. India (Bot. Ser.) 6:185, pl. 2. 1913. Sacc., Syll. Fungorum 25:651. 1931.

*Moniliaceae*. Mycelium effuse, grayish white; hyphae sparingly septate,  $3-5\ \mu$  diam.; conidia borne on short, simple or branched conidiophores, hyaline, oval to ovoid or long elliptical, continuous,  $4-12 \times 2-3\ \mu$ . This fungus causes a wilt disease marked by internal purple or dirty-red coloration and drying up of infected canes. Argentina, Barbados, British West Indies, Colombia, Guadeloupe, India, Mexico, Philippine Islands, Trinidad, Union South Africa, Uganda. *Wilt.*

CERATOSTOMELLA ADIPOSUM (Butler) Sartoris, Jour. Agric. Res. 35:577-585, 4 figs. 1927. *Stat. conid.*=*Sphaeronema adiposum* Butler, Mem. Dept. Agric. India (Bot. Ser.) 1:40, figs. 47-61. 1906. Sacc., Syll. Fungorum 22:926-7. 1899.

*Sphaeriaceae*. Mycelium dark brown; fertile hyphae bear endoconidia, varying from cylindrical to pyriform or globose, hyaline to brown, smooth to verrucose,  $9-25 \times 4.5-18\ \mu$ ; pycnidia globose, black, long beaked; conidia hyaline,  $6.5 \times 3.5\ \mu$ ; perithecia long beaked; spores crescent shaped,  $6.5-8 \times 3.5-4\ \mu$ . Causes a dark purple to black, soft, watery rot of seed cane with odor similar to that produced by *Ceratostomella paradoxa*. Davidson (Jour. Agric. Res. 50: 802, fig. 3, 1935) accepts the genus *Endoconidiophora* Münch (differentiated from *Ceratostomella* by endogenous conidia of the imperfect stage) and proposes the new combination *E. adiposa* (Butler) Davidson. Butler (Fungi and Disease in Plants, p. 383, 1918) suggested that possibly *Catenularia echinata* should be referred to this species. Brazil, Dominican Republic, India, Peru, United States. *Black rot.*

CERATOSTOMELLA PARADOXA (de Seynes) Dade, Trans. Brit. Myc. Soc. 13:184-194, 3 pls. 1928. *Sporochisma paradoxum* de Seynes, Recherches Veg. Infer. III, p. 30, figs. 22-24. 1886. *Chalara paradoxa* (de Seynes) Sacc., Syll. Fungorum 10:595. 1892. *Thielaviopsis ethaceticus* Went, Archief. v. d. Java Suikerind. 1:124, pl. 3. 1893. Wakker and Went, Ziekten v. h. Suikerriet op Java, pp. 44-49, pl. IV (col.). 1898. Petch, Ann. Roy. Bot. Garden Peradeniya 4:511. 1910. *Stat. conid.*=*Thielaviopsis paradoxa* (de Seynes) v. Hoeh., Hedw. 43:295. 1904. Butler, Mem. Dept. Agric. India (Bot. Ser.)



1:32-34, figs. 37-46. 1906. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:235. 1917. Miyake, Sugar Expt. Sta. Formosa Bull. 10, 2 col. pls. 1919.

*Sphaeriaceae*. Endoconidia hyaline, catenulate,  $10-15 \times 3.5-5 \mu$ ; macroconidia ovate, fuscous, catenulate,  $14-19 \times 10-12 \mu$ ; perithecia black, immersed, 200-350  $\mu$  diam.; beaks long, black, shining, with fimbriate tips, 800-1200  $\mu$ ; spores ellipsoid,  $7-10 \times 2.5-4 \mu$ . Causes an internal black rot of seed pieces, with a characteristic "pineapple odor." Sundararaman (Rept. Dept. Agric. Madras 1927-28:355-92, 1928) successfully infected sugar cane with this fungus from the bleeding disease of Palmyra palms. Massee erroneously reported *Thielaviopsis* as a form of his *Trichosphaeria sacchari*. Davidson (l. c.), following Münch, proposes the new combination *Endoconidiophora paradoxa* (de Seynes) Davidson for this fungus.

*Pineapple disease.*

Antigua, Argentina, Barbados, Brazil, British Guiana, Ceylon, Colombia, Cuba, Dominican Republic, Fiji, Formosa, Guadeloupe, Hawaii, India, Jamaica, Japan, Java, Madeira, Mauritius, Mexico, Philippine Islands, Puerto Rico, Queensland, Reunion, St. Kitts, St. Lucia, St. Vincent, Southern United States (Florida, Louisiana, Mississippi), Surinam, Tahiti, Trinidad. Also on *Saccharum spontaneum*. India.

CERCOSPORA ACEROSUM Dickh. and Hein, Archief. v. d. Java Suikerind. 9:1013, 2 pls. 1901. Sacc., Syll. Fungorum 18:611. 1906. (As *C. acerosa*).

*Dematiaceae*. Conidia 1-6 septate,  $10-50 \times 2-3.5 \mu$ , on dark brown irregular spots at juncture of leaf blade and sheath. Java, Philippine Islands.

*Black spot.*

CERCOSPORA KOPKEI Krüger, Ber. Zuck. in West-Java 1:115, pls. VI (col.), VIII B (figs. 1-5). 1890. Sacc., Syll. Fungorum 10:656. 1892. Wakker and Went, Ziekten Suikerriet op Java, pp. 141-144, pls. XVII, XVIII (figs. 9-11). 1898. Bolle, Arch. Suikerindus. Ned.-Indië, 1931, III:1189-1206. 1931.

*Dematiaceae*. Purple brown, amphigenous spots on leaf blades, irregular in shape, often confluent; conidia subhyaline, fusoid, 3-4 septate,  $20-50 \times 5-8 \mu$ . Also occurs on *Saccharum spontaneum*.

*Yellow spot.*

Argentina, Barbados, Brazil, British Guiana, Burma, China, Colombia, Cuba, Formosa, India, Indo-China, Java, New Guinea, Philippine Islands, Queensland, Reunion, Trinidad, and Tobago.

CERCOSPORA LONGIPES Butler, Mem. Dept. Agric. India (Bot. Ser.) 1:41-44, figs. 13-21. 1906. Sacc., Syll. Fungorum 22:1432. 1913. Butler, Fungi and Disease in Plants, pp. 405-6, fig. 168. 1918.

*Dematiaceae*. Conidiophores  $100-200 \times 4 \mu$ ; conidia obclavate, straight or curved, hyaline, 4-6-septate,  $40-80 \times 5 \mu$ . Spots on leaf blades, narrow, oval, amphigenous, at first 4 mm wide, reddish-brown with brown center and yellow areole; finally centers ashen with deep brown ring,  $15 \times 4 \mu$ .

*Brown spot.*

Argentina, Brazil, British West Indies, Colombia, Cuba, India, Java, Madagascar, Mauritius, Peru, Philippine Islands, Puerto Rico, Reunion, Southern United States (Florida, Louisiana), Tanganyika, Trinidad, Uganda.

*Cercospora sacchari* v. Breda de Haan See *Helminthosporium sacchari* (v. Breda de Haan) Butler Eye spot.

CERCOSPORA SORGHI Ell. and Everh. Jour. Myc. 3:15. 1887. Sacc., Syll. Fungorum 10:656. 1892.

*Dematiaceae*. This species originally described on *Holcus* and *Zea*, produced slight infections on sugarcane leaves following wound inoculations. India.

CERCOSPORA TAIWANENSIS Matsumoto and Yamamoto, Jour. Soc. Trop. Agric. (Formosa) 6:590-591, fig. 1. 1934. Kiryu Rept. Gov't Sugar Expt. Sta. Taiwan (Formosa) 3:19-28, pls. 4-5. 1936.

*Dematiaceae*. Conidiophores nonfasciculate, subhyaline to olivaceous brown, 1-6 septate,  $7-55 \times 2.5-4 \mu$ ; conidia obclavate-filiform, straight or slightly curved, hyaline, 2-15 septate,  $29-153 \times 2.5-3.7 \mu$ . Spots amphigenous, elliptical or elongated,  $2-10 \times 1-1.5 \text{ mm}$ , yellowish, dotted with red, coalescing into long streaks or bands and becoming darker in color; infected leaves drying up and dying. Formosa (Taiwan).

CERCOSPORA VAGINAE Krüger, Ber. Versuchssta. f. Zuckerohr West-Java 2:248-9, pl. I (figs. 1-3). 1896. Wakker and Went, Ziekten Suikerriet op Java, pp. 105-120, pls. XIII, XIV (col. fig. 1). 1898. Sacc., Syll. Fungorum 14:1106. 1899. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:199-200, pl. 29 (figs. 19, 20), pl. 24 (fig. 1). 1917.

*Dematiaceae*. Conidia 1-several septate,  $15-40 \times 4-8 \mu$ . Causing bright red spots on leaf sheaths, circular at first, then large and irregular, involving most of sheath, penetrating deeply, finally with black fruiting patches at center.

*Red spot of leaf sheath.*

Argentina, Barbados, Brazil, British Guiana, China, Colombia, Cuba, Dominican Republic, Formosa, Haiti, Hawaii(?), Honduras, India, Indo-China, Jamaica, Japan, Java, Lesser Antilles, Mauritius, Mexico, Philippine Islands, Puerto Rico, Queensland, Reunion, Siam, Southern United States, Trinidad, Union South Africa. On *Saccharum spontaneum*, Formosa.

CHAETOMELLA SACCHARI Delacroix, Bull. Soc. Myc. France 13:123, pl. X (fig. c). 1897. Sacc., Syll. Fungorum 14:925. 1899.

*Phomaceae*. Pycnidia flattened, subspherical, setose; conidia broadly fusoid,  $10-18 \times 9 \mu$ . On dead stalks. Madeira, Peru, Reunion.

CHAETOMIUM GLOBOSUM Kunze, Myc. Hefte 1:15-16, fig. 9 a-d. 1817. Sacc., Syll. Fungorum 1:222. 1882.

*Sphaeriaceae*. Perithecia  $225-250 \mu$  diam.; lateral and terminal hairs numerous, interwoven, dark olive, spores dark olive brown, ovate to lemon-shaped, apiculate,  $10.5 \times 8.5 \mu$ . On cane trash. Barbados.

CHAETOMIUM VIRIDE Lév., Ann. Sci. Nat. (3) 3:65. 1845. Sacc., Syll. Fungorum 1:229. 1882.

*Sphaeriaceae*. Saprophyte on cane trash. Argentina. Not sufficiently well described to recognize further.

CHAETOPHOMA (?) MAYDIS Speg., Anal. Soc. Cien. Argentina 22:190. 1886. Sacc., Syll. Fungorum 10:218. 1892.

*Phomaceae*. Pycnidia globose,  $50-90 \mu$  diam.; conidia elliptical, hyaline,  $2.5-3.5 \times 1.5-2 \mu$ . On dead and rotting leaves. Brazil.

CHAETOSTROMA SACCHARI Mass., Grevillea 22:67. 1893. Sacc., Syll. Fungorum 11:655. 1895.

*Tuberculariaceae*. Circular to elongated, black, velvety patches up to 2 mm in diam.; sporodochia setose; setae straight, dark brown,  $80-150 \times 7-12 \mu$ ; conidia globose, dark brown,  $10-12 \mu$ . On dying leaves. Barbados.

*Chaetostroma sacchari* Speg. See *Chaetostroma saccharicolum* Sacc. and Syd.

CHAETOSTROMA SACCHARICOLUM Sacc. and Syd. in Sacc., Syll. Fungorum 14:1130. 1899. *Chaetostroma* (?) *sacchari* Speg., Rev. Fac. Agron. y Vet. 2:255. 1896.

*Tuberculariaceae*. Sporodochia black, sparse or solitary; setae straight, black,  $50-70 \times 3-5 \mu$ ; conidia catenulate, fusiform, olivaceous,  $7-12 \times 3-5 \mu$ . On rotten cane trash. Argentina.

*Chalara paradoxa* (de Seynes) Sacc. See *Ceratostomella paradoxa* (de Seynes) Dade

CHONDROMYCES SACCHARI Speg., Rev. Fac. Agron. y Vet. 2:252. 1896. Sacc., Syll. Fungorum 14:842-3. 1899.

*Myxobacteriaceae*. Conidia obtusely rounded, 1-celled, hyaline,  $16-25 \times 8-18 \mu$ . On rotting cane trash. Argentina.

CHROMOCREA GELATINOSA (Tode) Seaver, Mycologia 2:58, pl. 20 (figs. 11-13). 1910. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:212. 1917. *Hypocrea gelatinosa* (Tode) Fr., Summa Veg. Scand., p. 383. 1849. Sacc., Syll. Fungorum 2:524. 1883.

*Hypocreaceae*. Stromata fleshy, bright lemon-yellow, finally punctate with greenish dots, 1-4 mm in diam.; asci 16-spored; spores green, finally brown,  $5 \mu$  in diam. On dead and dying leaf sheaths. Puerto Rico.

CHROMOCREOPSIS STRIISPORA Stevenson, Jour. Dept. Agric. P. Rico 1:213. 1917. Sacc., Syll. Fungorum 24:1339. 1928.

*Hypocreaceae*. Stromata few, scattered subglobose or flattened to substipitate, 1-3 mm diam.; spores ovoid to elliptical, striate,  $20-22 \times 5-7 \mu$ . On dead stalks. Puerto Rico.

CHYTRIDIUM sp.

An unnamed species parasitic in roots of cane affected with root-rot or Lahaina disease. (Hawaiian Planters' Rec. 21:2-8. 1919.)

CINTRACTIA PULVERULENTA Cke. and Mass., Grev. 18:34. 1889. Sacc., Syll. Fungorum 9:285. 1891.

*Ustilaginaceae*. Black fungus masses replacing ovaries; sporeballs subrotund or ovoid,  $40-50 \mu$  diam.; spores about 40 per ball, globose, verruculose, fuscous,  $8-10 \mu$ . On *Saccharum arundinaceum*. India.

CIRCINELLA SYDOWII Lendner, Bull. Soc. Bot. Genève (ser. 2) 5:29, illus. 1913. Sacc., Syll. Fungorum 24:6. 1926.

*Mucoraceae*. Spores spherical, gray,  $6-7 \mu$  diam. In sugar solutions. Union So. Africa.

*Citromyces* spp. See *Penicillium* spp.

*Citromyces pfefferianus* Wehmer See *Penicillium pfefferianus* (Wehmer) Pol-lacci

*CLADODERRIS DENDRITICA* (Pers.) Berk., London Jour. Bot. 1:152. 1842. Sacc., Syll. Fungorum 6:549. 1888. *Thelephora dendritica* Pers. in Freycinet Voy. Autor du Monde (Bot.), p. 176, pl. 1 (fig. 4). 1826.

*Thelephoraceae*. Sporophores erect, laterally stipitate, 10-15 cm in height; upper surface spongy, reddish-brown; hymenial surface with narrow, sharp radiating ribs. On dead stalks. Puerto Rico.

*CLADOSPORIUM* sp.

*Dematiaceae*. On dead cane. India. Sooty mold on stalks. Java. An agent of sugar deterioration. Louisiana.

*CLADOSPORIUM GRAMINUM* Lk. in Linn., Spec. Plantarum (Ed. 4) 1:42. 1824. Corda, Icones Fungorum I, p. 14, pl. III (fig. 207). 1837. Sacc., Syll. Fungorum 4:365. 1886. Avena Sacca, Bol. Agric. Sao Paulo 17:641, 1 fig. 1916.

*Dematiaceae*. Circular to irregular spots on canes, with definite borders, 1-2 cm diam.; conidia fuliginous, 1-2 septate,  $16-27 \times 10 \mu$ . On canes. Brazil.

*CLADOSPORIUM HERBARUM* (Pers.) Lk. Mag. Ges. Naturf. Freunde 7:37. 1886. Sacc., Syll. Fungorum 4:350. 1886.

*Dematiaceae*. Green to gray-green mold; conidia 1-4 septate, brown to olive green, oblong to ovoid. On cut cane leaves and cane trash. Argentina, Hawaii, Puerto Rico.

*CLADOSPORIUM (DEMATIUM) JAVANICUM* Wakker, Archief. v. d. Java-Suikerind. 4:889-92, pl. XVIII. 1896. Wakker and Went, Ziekten Suikerriet op Java, p. 197, pl. XXIII. 1898. Sacc., Syll. Fungorum 14:1082. 1899.

*Dematiaceae*. Gray-green mold; conidia hyaline, oblong,  $2.5-3 \times 1.5-2 \mu$ . On dead roots and leaves. Java. Delacroix (Maladies d. Plantes Cult. d. les Pays Chauds, p. 552, pl. LXVI (fig. 7). 1911) uses Wakker's alternate name *Dematium javanicum* Wakker.

*CLATHRUS COLUMNATUS* Bosc, Mag. Gesell. Naturf. Freunde 5:85. 1811. Sacc., Syll. Fungorum 7:18. 1888. *Laternea columnata* (Bosc) Nees in Nees and Henry, System der Pilze Abt. 2, p. 96, pl. 23. 1858. *Clathrus trilobatus* Cobb, Hawaiian Sugar Planters' Association, Div. Path. and Phys. Bull. 5:209. 1906.

*Phallaceae*. Sporophores consisting of 2-5 spongy columns, joined at tips, pink to red within, paler without; dark slimy gleba borne on under side of joined tips; spores smooth, elliptical,  $4-5 \times 2-3 \mu$ . Saprophytic on cane trash. Cobb considered his species one of the causes of root rot. Hawaii, Southern United States (Florida, Louisiana).

*Clathrus trilobatus* Cobb See *Clathrus columnatus* Bosc

*Clavaria gracillima* Wakker See *Clavaria wakkeri* Sacc. and Syd.

*CLAVARIA WAKKERI* Sacc. and Syd. in Sacc., Syl. Fungorum 14:237. 1899.

*Clavaria gracillima* Wakker in Wakker and Went, Ziekten suikerriet op Java, p. 195. 1898.

*Clavariaceae*. Sporophores erect, filiform, solitary or 2-5 fascicled, brittle; spores ovoid, hyaline,  $8 \times 5 \mu$ . On dead leaves. Java.

## CLAVICEPS sp.

*Hypocreaceae*. Sclerotia replacing ovaries, curved, rugulose, purple-black, white within. In arrows of seedling canes. Philippine Islands. Not specifically named, but probably *C. purpurea* (Fr.) Tul., Ann. Sci. Nat. III, 20-43, pl. 3. 1853. Ocfemia, Phil. Agric. 19:585. 1931.

COCHLIOBOLUS STENOSPILUS (Carp.) Matsumoto and Yamamoto, Jour. Plant Bot. 23:9-14, 107-115, 7 figs. 1936 (Japanese). *Ophiobolus stenospilus* Carpenter in Cook, Cong. Internatl. Soc. Sugarcane Technol. (4) Bull. 128:7. 1933.

*Sphaeriaceae*. (Nomen nudum) an ascigerous stage developing in cultures of *Helminthosporium stenospilum* and agreeing with that assigned by Carpenter to *Ophiobolus*. Formosa, Japan.

*Coleroa sacchari* v. Breda de Haan See *Eriosphaeria sacchari* (v. Breda de Haan) Went

COLLETOTRICHUM FALCATUM Went, Arch. Java Suikerindus. 1:271, pls. V, VI. 1893. Sacc., Syll. Fungorum 11:570. 1895. Wakker and Went, Ziekten Suiekrriet. op Java, pp. 36-44, 193, pl. 3 (col.). 1898. Butler and Khan, Mem. Dept. Agric. India (Bot. Ser.) 6:151-178, 1 pl. 1913. Edgerton, La. Agric. Exp. Sta. Bull. 120, 28 pp., illus., 1910, and 133, 22 pp., illus., 1911. Miyake et al, Sugar Exp. Sta. Formosa Bull. 4, 6 col. pls. Abbott, U. S. Dept. Agric. Tech. Bull. (In press). 1938.

*Melaconiaceae*. Sporodochia black velvety; setae numerous,  $100-200 \times 4 \mu$ ; conidia 1-celled,  $16-48 \times 4-8 \mu$ . Parasitic on leaf midribs and in stalks of species of *Saccharum*, and on leaf midribs of *Sorghum vulgare*, *S. halepense*, and *Erianthus giganteus*. In some regions causes wilt and death of infected sugar canes; interior characterized by reddened areas with white centers. Disease noted for sudden outbreaks (Java, West Indies, Louisiana). Abbott (l. c.) described morphologic races, identified in oatmeal-agar culture by compact, dark, velvety turf (dark races) and cottony, floccose mycelium (light races); also physiologic specialization within races. *Red rot*.

Antigua, Argentina, Barbados, Brazil, British Guiana, Central America, China, Colombia, Cuba, Dominican Republic, Egypt, Fiji, Formosa, Guadeloupe, Haiti, Hawaii, India, Indo-China, Jamaica, Japan, Java, Madagascar, Madeira, Mauritius, Mexico, Peru, Philippine Islands, Puerto Rico, Queensland, Reunion, St. Kitts, St. Lucia, Southern United States, Trinidad, Uganda, Union South Africa, Virgin Islands. Massee erroneously considers this species a form of his *Trichosphaeria sacchari*.

COLLETOTRICHUM GRAMINICOLUM (Cesati) Wilson, Phytopath. 4:106-112. 1914. Sacc., Syll. Fungorum 25:570. 1931. Böning and Wällner, Phytopath. Zeits. 9:99-110. 1936. Abbott, U. S. Dept. Agric. Tech. Bull. (In press). 1938. *C. lineola* Corda, from *Sorghum halepense* in Louisiana and *C. cereale* Manns from Ohio failed to produce red rot in sugarcane (Edgerton, La. Agr. Exp. Sta. Bull. 133, pp. 7-8, 1911).

*Melanconiaceae*. Setae  $115 \mu$  long; conidia  $23.6-40.8 \times 4.3-6.5 \mu$  (Böning and Wällner),  $15-23 \times 4 \mu$  (Abbott),  $18-26 \times 3-4 \mu$  (Selby and Manns for *C. cereale*), variously described as straight, spindle or sickle-shaped. Cultures from Iowa and Baarn failed to infect sugarcane in spite of certain morpholog-

ical similarities with *C. falcatum*. Evidently considerable diversity of characters among the various fungi classified under this species (Abbott, l. c.).

*Anthracnose.*

COLEODICTYOSPORA CUBENSIS Charles, Phytopath. 19:1051-2, fig. 1. 1929.

*Dematiaceae*. Hyphae scanty, septate, hyaline to light fuscous; conidiophores fasciculate, septate,  $70-85 \times 3.5-5 \mu$ ; conidia transversely oblong, muriform, constricted at center, tawny-olive,  $42-50 \times 20-22 \mu$ , with hyaline envelope. On dead cane. Cuba.

CONIOSPORIUM ARUNDINIS (Cda.) Sacc., Michelia 2:124. 1882. Sacc., Syll. Fungorum 4:243. 1886. *Gymnosporium arundinis* Cda., Icones Fung. 2:1, pl. 8 (fig. 1). 1838. *Papularia arundinis* (Cda.) Fr., Summa Veg. Scand., p. 509. 1849.

*Dematiaceae*. Acervuli black; conidia black, spherical, 1-guttulate,  $8-12 \mu$  diam. On dead culms. Alabama, Philippine Islands. Mason has [Annotated Account Fungi Received at Imp. Myc. Inst. List II (fasc. 2), p. 16] transferred this form to *Papularia sphaerosperma* (Pers.) v. Hoeh, Frag. z. Mykol., 20:990. 1916.

*Coniosporium extremorum* Syd. See *Nigrospora sphaerica* (Sacc.) Mason

CONIOSPORIUM SACCHARI Speg., Rev. Fac. Agron. y Vet. 2:248. 1896. Sacc., Syll. Fungorum 14:1069. 1899.

*Dematiaceae*. Acervuli minute, hemispherical, black; conidia opaque, globose,  $8-9 \mu$  diam. On rotten leaves and stalks. Argentina.

*Coniosporium vinosum* (Berk. and Curt.) Sacc. See *Papularia vinosa* (Berk. and Curt.) Mason

CONIOTHYRIUM spp.

*Phomaceae*. An undetermined form following "cold chlorosis." Cuba. On dead cane. Haiti, Trinidad.

*Coniothyrium melasporum* (Berk.) Sacc. See *Microdiplodia melaspora* (Berk.) Griff. and Maubl.

CONIOTHYRIUM OLIVACEUM Bon. in Fekl., Sym. 377. 1869. Sacc., Syll. Fungorum 3:305. 1884.

*Phomaceae*. Pycnidia scattered, erumpent, on irregular dead areas on leaves,  $300-350 \mu$  diam.; conidia elliptical-oblong, brown-olivaceous,  $5-8 \times 2-5 \mu$ . On living leaves. Cuba.

*Coniothyrium sacchari* (Mass.) Prill. and Delacr. See *Melanconium sacchari* Mass.

CORETHROPSIS ELEGANS Speg., Rev. Fac. Agron. y Vet. 2:245. 1896. Sacc., Syll. Fungorum 14:1044. 1899.

*Moniliaceae*. Conidia acrogenous, solitary, globose, ovoid or ellipsoidal, hyaline,  $10 \times 8-9 \mu$ . On dead and dying leaves. Argentina.

*Corioloopsis occidentalis* (Kl.) Murr. See *Polyporus occidentalis* Kl.

CORTICIUM spp.

*Thelephoraceae*. Several undetermined forms on rotten cane trash. Puerto Rico, Queensland (spreading from tree stumps on new land).

CORTICIUM ARACHNOIDEUM Berk., Ann. and Mag. Nat. Hist. 13:345, pl. 9 (fig. 3). 1844. Sacc., Syll. Fungorum 6:611. 1888. Burt, Ann. Mo. Bot. Garden 13:184. 1926.

*Thelephoraceae*. Thin, arachnoid, 2-6 cm long; hymenial layer snow-white; spores hyaline, globose or subglobose, 4-6  $\mu$  diam. On cane trash. Puerto Rico.

CORTICIUM CENTRIFUGUM (Lév.) Bres., Ann. Myc. 1:96. 1903. V. Hoehnel, Ann. Myc. 3:188. 1905. Burt, Ann. Mo. Bot. Garden 13:206-8. 1926. *Hypochnus centrifugus* (Lév.) Tul., Fung. Carp. 1:113. 1861. Sacc., Syll. Fungorum 6:654. 1888.

*Thelephoraceae*. Fructifications thin, effused, arachnoid, fragile, white, rarely with clamp connections, no gloecystidia; spores hyaline, smooth, ellipsoidal, 4-8  $\times$  2.5-4  $\mu$ . As *Hypochnus*, Japanese workers use this binomial for the perfect stage of *Sclerotium rolfsii* (q. v.).

*Corticium rolfsii* Curzi See *Sclerotium rolfsii* Sacc.

CORTICIUM SALMONICOLOR Berk. and Br., Linn. Soc. Bot. Jour. 14:71. 1873. Sacc., Syll. Fungorum 6:620. 1888. Burt, Ann. Mo. Bot. Garden 13:227-8. 1926.

*Thelephoraceae*. On P O J 2878. Java.

*Corticium sasakii* Shirai. See *Hypochnus sasakii* Shirai.

CORTICIUM VAGUM Berk. and Curt., Grevillea 1:179. 1873. Sacc., Syll. Fungorum 6:616. 1888. Burt, Ann. Mo. Bot. Garden 13:295-7, 1 fig. 1926. *Rhizoctonia solani* Kuehn, Krankheit. v. Kulturgewachse, p. 224. 1858. Duggar, Ann. Mo. Bot. Garden 2:424. 1915.

*Thelephoraceae*. Sclerotia flattened, black, irregular, on underground part or at surface of soil; hymenium thin, arachnoid, sheathing stems, olive buff to cream; spores hyaline, smooth, flattened on one side, 8-14  $\times$  4-6  $\mu$ . Parasitic on cane roots and fruiting at base of living canes or on trash. Barbados, British Guiana, India, Louisiana, Mauritius, Philippine Islands, Puerto Rico.

CRATERIUM AUREUM (Schum.) Rost., Monog., p. 124. 1875. Macbride and Martin, The Myxomycetes, p. 94, pl. VI (figs. 131-2). 1934.

*Physaraceae*. Sporangia stipitate, golden yellow; spores minutely warted, violaceous brown, 8-10  $\mu$  diam. On cane trash. Dominican Republic, Puerto Rico.

CRATERIUM LEUCOCEPHALUM (Pers.) Ditm. in Sturm, Deutschl. Fl. Pilze, p. 121. 1813. Macbride and Martin, The Myxomycetes, p. 95, pl. VII (figs. 133-5). 1934.

*Physaraceae*. Sporangia short cylindrical, stipitate, white above, brown or reddish-brown below; spores minutely spinulose, violaceous brown, 8-9  $\mu$  diam. On cane trash. Puerto Rico.

CREPIDOTUS sp.

*Agaricaceae*. An undetermined species on cane trash. Puerto Rico.

CURVULARIA spp.

*Dematiaceae*. *Acrothecium* spp., not specifically named, now to be referred to *Curvularia*, on dead leaves. Java and other cane regions. Wakker and

Went (l. c., p. 151) mention an *Acrothecium* associated with ring-spot lesions, but not a stage of *Leptosphaeria*. In Louisiana, a form isolated from diseased roots, but "probably of no significance."

**CURVULARIA LUNATA** (Wakker) Boedijn, Bull. Jard. Bot. Buitenz. III, 13-127, figs. 3-4. 1933. *Acrothecium lunatum* Wakker in Wakker and Went, Ziekten Suikerriet op Java, p. 196. 1898. Sacc., Syll. Fungorum 14:1089. 1899.

*Dematiaceae*. Conidia brown, somewhat curved, 3-septate, upper-central cell larger and darker than others, average  $23 \times 11 \mu$ . On dead leaves and culms. Gold Coast, Hawaii, India, Java, Uganda.

**CYATHUS POEPPIGII** Tul., Ann. Sci. Nat. III, 1:77, pl. 4 (figs. 23-25). 1844. Sacc., Syll. Fungorum 7:37. 1888. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:219, pl. 23 (fig. 6). 1917.

*Nidulariaceae*. Peridia dark brown, deeply striate, 7-12 mm high, 5-7 mm wide at top; spores,  $38-45 \times 18-22 \mu$ . On dead canes. Puerto Rico.

**CYTOSPORA SACCHARI** Butler, Mem. Dept. Agric. India (Bot. Ser.) 1:31, pl. VIII. 1906. Sacc., Syll. Fungorum 22:962. 1913. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:196-8, pl. 22 (fig. 1-2), pl. 28 (figs. 1-4). 1917. Kiryu, Rep. Gov't Sugar Exp. Sta. Taiwan (Formosa) 4:172-94, 2 pls. 1937.

*Phomaceae*. Mycelium killing and binding leaf sheaths, killing young shoots, forming irregular brown cankers on older stalks; infected sheaths dark red, roughened by projecting necks of pycnidia which are immersed; conidia cylindrical to curved, ends obtuse, hyaline,  $3.5 \times 1-1.5 \mu$ . On leaf sheaths and stalks.

*Sheath rot.*

Argentina, Barbados, Brazil, Cochin-China, Cuba, Formosa, Georgia, India, Java, Lesser Antilles, Louisiana, Philippine Islands, Puerto Rico. Avena-Sacca (Brazil) reports a perfect stage, but his organism appears different (Bol. Agric. Sao Paulo 17:619-623, 3 figs., 1916). See also *Leeina philippinensis*.

**DACROMYCES SACCHARI** Berk. and Br., Trans. Linn. Soc. London (2) 2:65. 1883. Sacc., Syll. Fungorum 6:800. 1888.

*Dacryomycetaceae*. Reddish-yellow gelatinous masses; spores subglobose. On charred cane. Queensland.

*Darlucella melaspora* Berk. See *Microdiplodia melaspora* (Berk.) Griff. and Maubl.

**DASYSCYPHA** sp.

*Helotiaceae*. An undetermined species on cane trash. Puerto Rico.

*Dematium javanicum* Wakker See *Cladosporium javanicum* Wakker

**DEMATIUM LEVISPORUM** Speg., Anal. Mus. Nac. Hist. Buenos Aires (3) 13:443. 1910. Sacc., Syll. Fungorum 22:1357-8. 1913.

*Dematiaceae*. Conidia globose, smooth, fuliginous,  $5-7 \mu$ . On rotten culms. Argentina.

*Dendrophoma* (?) *saccharicola* Avena Sacca See *Hendersonia saccharicola* (Avena-Sacca) Trotter

**DEPAZEA SACCHARI** Berk.

*Phomaceae*. Reported as saprophytic on leaves, Queensland, by Caum, but no further record found.



DIAPORTHE SACCHARI Speg., Anal. Mus. Nac. Buenos Aires 19:364. 1909. Sacc., Syll. Fungorum 22:386. 1913.

*Sphaeriaceae*. Perithecia 120-150  $\mu$  diam.; asci 8-spored, 65-90  $\times$  14-18  $\mu$ ; spores subfusoid, often slightly curved, 1-septate, 20-30  $\times$  5-7  $\mu$ . Rotten culms. Argentina.

DICTYDIUM CANCELLATUM (Batsch) Macbr., N. Amer. Slime-moulds, p. 172. 1899.

*Cribrariaceae*. Sporangia stipitate, brown or brownish-purple; stipe 2 to 10 times length diameter of sporangia, 5-6 mm high; spores brown to purple, smooth, 5-7  $\mu$ . On cane trash. Puerto Rico.

DICTYOPHORA INDUSIATA (Vent. ex Fr.) Fischer, Unter. Phall. Surinam, p. 28. 1928. Cunningham, Proc. Linn. Soc. New So. Wales 56:12. 1931. *Dictyophora phalloidea* Desv., Jour. de Bot. 2:88. 1809. Sacc., Syll. Fungorum 7:3. 1888.

*Phallaceae*. Receptacle white, hollow, 20  $\times$  3.5 cm; pileus campanulate, dingy white, rugulose; veil coarsely net-like, white, pendant; gleba olivaceous, fetid; spores elliptical, smooth, 3.5-4.5  $\times$  1.5-2  $\mu$ . Growing in and about cane stools suffering from root rot, but very doubtfully parasitic. Dutch E. Indies, Hawaii, Philippine Islands.

DICTYOPHORA MULTICOLOR Berk. and Br., Trans. Linn. Soc. London ser. 2, 2:66, pl. XIV (fig. 16). 1883. Sacc., Syll. Fungorum 7:7. 1888. Cunningham, Proc. Linn. Soc. New So. Wales 56:112-13. 1931. Bouriquet, Rev. Path. Veg. and Entom. Agr. 18:220-4, pl. X. 1931. *Phallus multicolor* (Berk. and Br.) Lloyd, Myc. Writ. 2:Ph. A. 6, fig. 3. 1907.

*Phallaceae*. Receptacle white below, pink above, hollow, 16  $\times$  3 cm; pileus conical, orange; gleba olivaceous, fetid; veil pendant, salmon-pink, with fine meshes; spores elliptical, 3-5  $\times$  1.8  $\mu$ . Associated with root disease. Madagascar.

*Dictyophora phalloidea* Desv. See *Dictyophora indusiata* (Vent. ex Fr.) Fischer

DIDYMOSPIAERIA SACCHARICOLA Speg., Anal. Mus. Nac. Buenos Aires 19:370. 1909. Sacc., Syll. Fungorum 22:175. 1913.

*Sphaeriaceae*. Perithecia 150-180  $\mu$  diam.; asci, 8-spored, 110-120  $\times$  8  $\mu$ ; paraphyses filiform; spores elongate, elliptical, 1-septate, fuliginous, 15  $\times$  5  $\mu$ . On rotten culms. Argentina.

DINEMASPORIUM SACCHARI P. Henn., Hedw. 44:71. 1905. Sacc., Syll. Fungorum 18:441. 1906.

*Discellaceae*. Pycnidia superficial, 180-200  $\mu$  diam., on amphigenous oblong or circular, pale brown spots with red-brown borders; setae black, rigid, 120-200  $\times$  4  $\mu$ ; conidia fusoid to subfalcate, hyaline, ciliate, 10-18  $\times$  2.5-3  $\mu$ ; cilia 5-10  $\mu$ . Caum states "possibly a variety of *D. gramineum* Lév." Peru.

*Dioranotropis vastatrix*.

The above combination appears in an anonymous paper in Rev. Agric. Reunion 6:5-11, 1900, the author stating that, along with *Cercospora vaginac*, *Ustilago sacchari*, and other "maladies cryptogamiques," it possibly occurs in Reunion, producing red or black spots on the leaf-sheaths. As a doubtful

entity, it has been listed by Caum, Clements and Shear (p. 413) and Saccardo in Syll. Fungorum 24:1321, 1928. As S. F. Ashby has pointed out (recent letter in response to our inquiry), the homopterous insect, *Dicranotropis vastatrix* Breddin is undoubtedly what the original author had in mind. This insect is listed by Krüger (Das Zuckerrohr und seine Kultur, p. 312) for Java.

*Diplodia cacaoicola* P. Henn. See *Physalospora rhodina* (Berk. and Curt.) Cke.  
*Endoconidiophora adiposa* (Butl.) Davidson See *Ceratostomella adiposum* (Butl.) Sartoris

*Endoconidiophora paradoxa* (De Seynes) Davidson See *Ceratostomella paradoxa* (De Seynes) Dade

#### ENDOXYLINA sp.

*Sphaeriaceae*. An unnamed species on weathered stalks. Brazil.

*Epicoccum levisporum* Pat. See *Nigrospora sphaerica* (Sacc.) Mason

EPICOCUM PURPURASCENS Ehrbg., Sylv. Myc. Berol., p. 12. 1818. Sacc., Syll. Fungorum 4:736. 1886.

*Tuberculariaceae*. Sporodochia globose, dark brown, 120-150  $\mu$  diam.; conidia subglobose, brown, verrucose, 16-22  $\mu$  diam. On dead leaves. Argentina, Southern Europe.

EPICOCUM VULGARE Cda., Icones Fung. 1:5, fig. 90. 1837. Sacc., Syll. Fungorum 4:737. 1886. Spegazzini, Rev. Fac. Agron. y Vet. 2:255. 1896.

*Tuberculariaceae*. Conidia dark, verrucose, globose, 21-25  $\mu$  diam. On dead and rotted leaves and culms. Argentina.

ERIOSPHAERIA SACCHARI (v. Breda de Haan) Went in Wakker and Went, Ziekten Suikerriet op Java, pp. 153-6, col. pl. 21 (figs. 6-9). 1898. *Coleroa sacchari* v. Breda de Haan, Meded. Proefsta. v. Suikerriet in West-Java 3:22-24. 1892. *Venturia sacchari* (v. Breda de Haan) Sacc., Syll. Fungorum 11:306. 1895.

*Sphaeriaceae*. Perithecia imbedded in brown, superficial mycelium on irregular brown spots, 45-75  $\mu$  diam., bearing lobed processes; spores 2-celled, 11-13  $\times$  5-6  $\mu$ . On leaves. Brit. W. Indies (?), Cuba, Java, North Coast South America, Trinidad. Clements and Shear (Genera of Fungi, p. 265, 1931) refer this genus to *Gibbera*. Red leaf spot.

*Erwinia ananas* Serrano See *Bacillus ananas* Serrano

*Erwinia sacchari* Roldan See *Bacillus sacchari* Roldan

ERYSIPHE GRAMINIS DC., Flore Fr. 6:106. 1815. Sacc., Syll. Fungorum 1:19. 1882.

*Erysiphaceae*. Black perithecia immersed in superficial dense patches of dirty white to gray mycelium, 135-280  $\mu$  diam.; asci numerous, 4- or 8-spored; spores 20-23  $\times$  10-13  $\mu$ . On living leaves. Italy. Powdery mildew.

*Eurotium argentinum* Speg. See *Aspergillus argentinus* Speg.

*Eurotium herbariorum* Lk. See *Aspergillus herbariorum* (Wiggers) Fischer

*Eurotium sacchari* Speg. See *Aspergillus sacchari* Speg.

EURYACHORA SACCHARI Averna Sacca, Bol. Agric. Sao Paulo 17:618, 2 figs. 1916. Sacc., Syll. Fungorum 24:1334. 1928.

*Dothideaceae*. Stromata subepidermal, erumpent; spores fusoid, fuliginous, 29-40  $\times$  16  $\mu$ . On culms. Brazil.

EUTYPELLA SACCHARI Speg., Anal. Mus. Nac. Buenos Aires (2) 3:244. 1899. Sacc., Syll. Fungorum 16:424. 1902.

*Sphaeriaceae*. Perithecia single or loosely aggregated, 150  $\mu$  diam.; spores elliptical, obtuse at both ends, hyaline,  $4-6 \times 2-4 \mu$ . On rotten leaves. Argentina.

FOMES sp.

*Polyporaceae*. An unnamed species (cf. *F. melanodermus* Pat., *F. Pachyphloeus* Pat.) associated with foot rot in newly cleared fields, marked by characteristic zoning of basal parts of diseased plants (Phytopath. 17:83-94, 10 figs. 1927). Infection attempts failed. Cuba. *Zonate foot rot*.

FOMES LORENTZIANUS Kalchbr., Abhandl. Geb. Naturwiss. Ungar. Akad. d. Wiss. Budapest 8:21, pl. III (fig. 1). 1879. Sacc., Syll. Fungorum 6:151. 1888. Spegazzini, Rev. Fac. Agron. y Vet. 2:227. 1896.

*Polyporaceae*. On dead stalks. Argentina.

FULIGO SEPTICA (L.) Weber in Wigg., Pr. Fl. Holsat., p. 112. 1780. Spegazzini, Rev. Fac. Agron. y Vet. 2:238. 1896. Machbride and Martin, The Myxomycetes, pp. 22-23. 1934.

*Physaraceae*. Aethalium puvinate, up to 20 cm diam., 1-3 cm thick, white, yellow ochraceous, greenish to brown or deep violet; spores in mass dull black, spherical, spinulose to nearly smooth,  $6 \times 9 \mu$ . On cane trash. Argentina, Puerto Rico.

FUMAGO sp.

*Dematiaceae*. Sooty mold on stalks. Java. See also *Capnodium*.

FUMAGO (?) SACCHARI Speg., Rev. Fac. Agron. y Vet. 2:256. 1896. Sacc., Syll. Fungorum 14:1099. 1899.

*Dematiaceae*. On culms and lower leaves. Argentina, Brazil.

*Sooty mold*.

FUSARIUM spp.

*Tuberculariaceae*. Fusaria, not specifically named, have been reported as commonly associated with root rot, wilting cane, dead and dying stalks, internal reddening of stalks, in seed cane possibly reducing germination, in top rot cases, on cane trash, as agents of sugar deterioration, etc. Argentina, Brazil, British Guiana, Cuba, Dutch E. Indies, Hawaii, India, Louisiana, Mauritius, Peru, Philippine Islands, Puerto Rico, Uganda.

FUSARIUM AVENACEUM (Fr.) Sacc., Syll. Fungorum 4:713. 1886. Wollenweber and Reinking, Die Fusarien, pp. 53-5, fig. 12. 1935.

*Tuberculariaceae*. Group *Roseum*; conidia,  $3-5$  septate,  $30-66 \times 2.5-3 \mu$  (average). Saprophytic on dead parts. Locality not reported.

*Fusarium moniliforme* Sheldon See *Gibberella fujikuroi* (Saw.) Wr.

*Fusarium moniliforme* Sheldon var. *majus* Wr. and Reinking See *Gibberella fujikuroi* (Saw.) Wr.

*Fusarium moniliforme* Sheldon var. *subglutinans* Wr. and Reinking See *Gibberella fujikuroi* (Saw.) Wr. var. *subglutinans* Edwards

*FUSARIUM OXYSPORUM* Schl. var. *aurantiacum* (Lk. ut sp.) Wr., Zeitschrift f. Parasitenk., 3:420. 1931. Wollenweber and Reinking, Die Fusarien, p. 121, fig. 27. 1935.

*Tuberculariaceae*. Reported on *Saccharum* by Wollenweber and Reinking (op. cit.) without detail.

*FUSARIUM SOLANI* (Mart.) App. and Wr. var. *minus* Wr., Ann. Myc. 15:55. 1917. Wollenweber and Reinking, Die Fusarien, p. 134, fig. 30. 1935

*Tuberculariaceae*. Reported by Wollenweber and Reinking (op. cit.) on *Saccharum* without detail.

*GIBBERELLA FUJIKUROI* (Saw.) Wr. in Nisikado, Ber. Ohara Inst. f. Landw. Forsch. 1:87-106, 4 pls. 1931. Wollenweber and Reinking, Die Fusarien, p. 99, fig. 22. 1935. *Stat. conid.*=*Fusarium moniliforme* Sheldon in Nebr. Agric. Exp. Sta. Rept. 17:23-32, illus. 1904. Sacc., Syll. Fungorum 22:1485. 1913. Wakker and Went, Ziekten Suikerriet op Java, p. 66, col. pl. VII. 1898. Bolle, Arch. Suikerindus. Ned.-Indië 1927, pp. 589-609, col. pl. 1; 1928, pp. 116-129. Priode, Phytopath. 19:343, illus., 1929; and 23:672-4, 1933. Wollenweber and Reinking op. cit., p. 262. 1935. (?) *Lisea australis* Speg. var. *sacchari* Speg., Rev. Fac. Agron. y Vet. 2:236. 1896. Sacc., Syll. Fungorum 14:640. 1899. *Gibberella moniliformis* (Sheldon) Winel., Jour. Agric. Res. 28:920, 2 pls., 6 figs. 1924. *Fusarium moniliforme* Sheldon var. *majus* Wr. and Reinking, Phytopath. 15:163-4. 1925.

*Hypocreaceae*. Microconidia in chains,  $5-10 \times 2-3.5 \mu$ ; conidia 3-5-, rarely 6-7-septate,  $20-70 \times 2-5 \mu$ ; no chlamydospores; occasional sclerotia; perithecia deep blue,  $.25-.33 \times .22-.28$  mm, paraphysate; spores 1-septate (rarely more),  $14-18 \times 4.4-7 \mu$ . Causing chlorotic spots with red specks and stripes on unfolding leaves, restricting elongation and resulting in severe malformation and often top rot. Ladder-shaped lesions and cavities covered with pink powder (conidia). Infects also corn and sorghum (Priode). *Lisea australis sacchari*, doubtfully referred here, was reported by Spegazzini on rotting culms, Argentina.

*Pokkah Boeng*, Top rot.

Australia, Brazil, Cuba, Dominican Republic, Fiji, Formosa, Hawaii, India, Indo-China, Japan, Java, Madagascar, Mauritius, Mexico, Peru, Philippine Islands, Puerto Rico, Reunion, Southern United States, Venezuela.

*GIBBERELLA FUJIKUROI* (Saw.) Wr. var. *SUBGLUTINANS* Edwards, Sci. Bull. Dept. Agric. New So. Wales 49:41, illus. 1935. *Stat. conid.*=*Fusarium moniliforme* Sheldon var. *subglutinans* Wr. and Reinking, Phytopath. 15:163. 1925.

*Hypocreaceae*. Differs from the species chiefly in that microconidia are not in chains. Hawaii.

*Gibberella moniliformis* (Sheldon) Wineland See *Gibberella fujikuroi* (Saw.) Wr.

*GIBBERELLA PULICARIS* (Fr.) Sacc., Michelia 1:317. 1879. Sacc., Syll. Fungorum 2:552. 1883. Spegazzini, Rev. Fac. Agron. y Vet. 2:236. 1896. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:213. 1917.

*Hypocreaceae*. Spores subobtuse, ovate-lanceolate, 3-septate,  $18-20 \times 6-8 \mu$ . On dead stems. Argentina, Puerto Rico.

GIBBERELLA SACCHARI Speg., Rev. Fac. Agron. y Vet. 2:237. 1896. Sacc., Syll. Fungorum 14:649-650. 1889.

*Hypocreaceae*. Spores,  $16 \times 3.5-4 \mu$ . On dead and rotting leaves and canes. Argentina.

GIBBERELLA SAUBINETII (Mont.) Sacc., Michelia 1:513. 1879. Sacc., Syll. Fungorum 2:554. 1883.

*Hypocreaceae*. Spores 3-septate,  $18-24 \times 4-5 \mu$ . On cane trash. Argentina. The fungus causing scab of cereals has been assigned to *G. zeae* (Schw.) Petch, Ann. Mycol. 34:256-60. 1936. As reported on cane substrata, the three species above are probably identical. *G. pulicaris* has priority.

*Glenospora sacchari* Speg. See *Nigrospora sacchari* (Speg.) Mason

GLIOCLADIUM sp.

*Moniliaceae*. Isolated from diseased roots. British Guiana.

GLIOCLADIUM ROSEUM (Lk?) Brainier, Bull. Soc. Myc. France 23:111-112, pl. XV (figs. 1-6). 1907. Thom, The Penicillia, pp. 504-5. 1930. *Penicillium roseum* Lk., Obs. Myc. II, p. 37. 1816. Sacc., Syll. Fungorum 4:83. 1886.

*Moniliaceae*. Colonies white to pink or salmon; conidia colorless (pink in mass), elliptical, slightly apiculate, smooth,  $5-7 \times 3-5 \mu$ . Isolated from sugar. Louisiana.

GLOMERELLA CINGULATA (Stonem.) Spaulding and v. Schrenk, Science 17:751. 1903 and U. S. Dept. Agric. Bur. Pl. Ind. Bull. 44:29, 9 pls. 1903.

*Sphaeriaceae*. Cultures from cane material. Louisiana.

GLYCYPHILA VERSICOLOR Mont., Bull. Soc. Nat. et Centr. d'Agric., p. 462. 1852. Mont., Syll. Crypt., p. 307. 1856. Sacc., Syll. Fungorum 4:11. 1886. (As *Glycophila*.)

*Moniliaceae*. Oospore-like; conidia spherical, rosy then olivaceous, agglomerated in heads. Mold on sugar. France.

GNOMONIA ILIAU Lyon, Hawaii. Sugar Plant. Assoc. (Path. and Phys. Ser.) Bull. 11:28, 1 col. pl., 10 figs. 1912. Sacc., Syll. Fungorum 24:1073. 1928. Stat. conid. = *Melanconium iliau* Lyon l. c. Sacc., Syll. Fungorum 25:582. 1931. Edgerton, Phytopath. 3:93-97, pl. 8. 1913.

*Sphaeriaceae*. Perithecia black, spherical with long curved necks, 350-450  $\mu$  diam.; spores hyaline, spindle-shaped, 1-septate,  $20-25 \times 3-5 \mu$ ; conidia dark brown to black, egg-shaped, nonseptate,  $15-22 \times 6-8 \mu$ . Parasitic in leaf-sheaths and stems, causing the disease *Iliau*. Australia, Brazil, Cuba, Hawaii, Louisiana, Mauritius, Philippine Islands (?).

GRAPHIUM spp.

*Stilbaceae*. Caum reports undetermined species on cane leaves about the wounds caused by leaf-hoppers. Hawaii.

GRAPHIUM NODULOSUM Marchal, Bull. Soc. Belge Micros. 20:266, pl. 7 (fig. 5). 1894. Sacc., Syll. Fungorum 11:644. 1895.

*Stilbaceae*. Synnema 1-1.5 cm tall, dark; conidia ovoid, hyaline,  $3.5-4.5 \times 2-2.5 \mu$ . On dead culms associated with *Nectria laurentiana* Marchal. Belgian Congo.

GRAPHIUM PISTILLARIOIDES Speg., Rev. Fac. Agron. y Vet. 2:254. 1896. Sacc., Syll. Fungorum 14:1110-11. 1899.

*Stilbaceae*. Synnema dark, 500-1000  $\mu$  tall; conidia smooth, ovate or elliptical,  $4-4.5 \times 2.5-3 \mu$ . On rotten leaves. Argentina, Cuba.

GRAPHIUM SACCHARI Speg., Rev. Fac. Agron. y Vet. 2:253. 1896. Sacc., Syll. Fungorum 14:1111. 1899. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:226, pl. XXVII (figs. 5-7). 1917.

*Stilbaceae*. Synnema densely aggregated, erect,  $500-1200 \times 20-40 \mu$ ; conidia ellipsoid or oval, hyaline, smooth,  $5-7 \times 4 \mu$ . On dead stalks, leaf blades and sheaths. Argentina, Dominican Republic, Puerto Rico.

GUEPINIA PALMICEPS Berk., Ann. Mag. Nat. Hist. 10:383, fig. 14. 1843. Sacc., Syll. Fungorum 6:809. 1888.

*Dacryomycetaceae*. Fruiting bodies stipitate, firm, gelatinous; tips yellow-red; spores not recorded. Dead stalks. Puerto Rico.

*Guepinia spathulata* Jungh. See *Guepinia spathularia* (Schw.) Fr.

GUEPINIA SPATHULARIA (Schw.) Fr., Elench. Fungorum 2:32. 1828. Sacc., Syll. Fungorum 6:807. 1888.

*Dacryomycetaceae*. Fruiting bodies spathulate, erect, stipitate, yellow, gelatinous, drying corneous, .5-2 cm tall; hymenium orange-yellow, rugose; spores smooth, orange-yellow, elliptical, on long deeply bipartite basidia,  $7.4-9.5 \times 3.8-4.5 \mu$ . On dead stalks. Puerto Rico. Erroneously reported (Jour. Dept. Agric. P. Rico 1:215, 1917) as *G. spathulata* Jungh.

GYMNOASCUS REESSII Baranetzky, Bot. Zeit. 30:158. 1872. Sacc., Syll. Fungorum 8:823. 1889.

*Gymnoascaceae*. Fruiting bodies 1 mm diam., golden yellow; spores globose or ovoid, brown,  $4-5 \times 3-3.5 \mu$ . On dead stalks. Java.

*Gymnosporium arundinis* Cda. See *Coniosporium arundinis* (Cda.) Sacc.

*Gymnosporium vinosum* Berk. and Curt. See *Papularia vinosa* (Berk. and Curt.) Mason

HANSENIA APICULATA (Reess) Lindner var. SACCHARI, Racib. Arch. v. d. Java Suikerind. 6:484, 1 fig. 1898. Guilliermond and Tanner, The Yeasts, pp. 273-4, 1 fig. 1920. *Saccharomyces apiculata* Reess var. *sacchari* Racib., l. c. Delacroix, Maladies Plant. Cult. dans des Pays Chauds, p. 538. 1911.

*Saccharomycetaceae*. Cells lemon-shaped,  $4 \times 2 \mu$ . Causing reddish bordered, gray, watery areas in seed-cuttings resulting in death of young dependent plants. Also as a sugar fermenting agent (?). Java. Clements and Shear (The Genera of Fungi, p. 246, 1931) propose *Thelis* to replace *Hansenia*.

HAPLOGRAPHIUM CHLOROCEPHALUM (Fres.) Grove subsp. DENSUM Sacc., Ann. Myc. 9:256. 1911. Sacc., Syll. Fungorum 22:1354. 1913.

*Dematiaceae*. Fascicles denser than in the species, sordid olivaceous; conidial heads 50-60  $\mu$  diam.; conidia catenulate, spherical, 1-guttulate, smooth, ochraceous to olivaceous, 4  $\mu$  in diam. On rotting canes. Madeira. Clements and Shear (The Genera of Fungi, p. 393, 1931) consider the genus synonymous with *Cephalotrichum*.

HAPLOGRAPHIUM SACCHARI Speg., Rev. Fac. Agron. y Vet. 2:249. 1896. Sacc., Syll. Fungorum 14:1076. 1899.

*Dematiaceae*. Conidiophores erect, rigid, dark, branched,  $150-250 \times 10-14 \mu$ ; conidia acrogenous, catenulate, globose, minutely roughened, dark-fuliginous,  $6-10 \mu$ . On dead and dying leaves and leaf-sheaths. Argentina.

*Haplosporella melanconioides* Sacc. See *Melanconium sacchari* Mass.

HAPLOSPORELLA SACCHARI da Camara, Anais do Inst. Sup. Agron. 3:108, figs. 75-77. 1930.

*Phomaceae*. Pycnidia erumpent, conidia 1-guttulate, brown,  $19-25 \times 9-11 \mu$ . On culms. Portugal.

HELMINTHOSPORIUM sp.

*Dematiaceae*. Conidia light brown, slightly curved,  $76 \times 15$  (average)  $\mu$ . Associated with irregular concentric rings or zonate spots on leaves and spindles which may coalesce to cover entire area of affected leaves, deep brown. Cuba. Described by Priode, Phytopath. 21:41-57, 1 col. pl., figs. 1-7. 1931. See also McRae, Sci. Repts. Imp. Inst. Agr. Res. India 1931-32, p. 129.

*Target-blotch.*

HELMINTHOSPORIUM HALODES Drechsler, Jour. Agric. Res. 24:709, pls. 22, 23 (figs. a-g.) 1923. Subramaniam, Indian Jour. Agr. Sci. 6:11-16, pl. IX-XI (1 col.). 1936.

*Dematiaceae*. Conidiophores  $60-150 \times 4-7 \mu$ ; conidia brownish yellow, apices rounded, 1-12 septate,  $20-105 \times 10-14 \mu$ . Cause of seedling disease. India.

HELMINTHOSPORIUM NODULOSUM Berk. and Curt., Grevillea 3:102. 1875. Sacc., Syll. Fungorum 4:421. 1886. McRae, Sci. Repts. Imp. Inst. Pusa, 1930-31:73-86. 1932. Mitra and Mehta, Indian Jour. Agr. Sci. 4:943-75. 1934.

*Dematiaceae*. Inadequately described. Small leaf-spots found on sugarcane from inoculations. India.

*Helminthosporium ocellum* Faris See *Helminthosporium sacchari* (v. Breda de Haan) Butler

HELMINTHOSPORIUM SACCHARI (v. Breda de Haan) Butler, Mem. Dept. Agric. India (Bot. Ser.) 6:207, pl. 6. 1913. Sacc., Syll. Fungorum 25:823. 1931. Johnston and Stevenson, Jour. Dept. Agric. Puerto Rico 1:202-3. 1917. Lee et al, Hawaii. Planters' Rec. 30:466-92. 1926. Mitra, Trans. Brit. Myc. Soc. 15:259-60, 289-90; 16:123-25. 1931. *Cercospora sacchari* v. Breda de Haan, Meded. Proefsta. Suikerriet West-Java 3:15-21. 1892. Sacc., Syll. Fungorum 11:629. 1895. Wakker and Went, Ziekten Suikerriet op Java, pp. 157-61, col. pl. 21 (figs. 1-5). 1898. *Helminthosporium ocellum* Faris, Phytopath. 18:757, col. pl. XV (figs. 3, 5, 7). 1928. Mitra (l. c.) and McRae (Sci. Repts. Imp. Inst. Agr. Res. 1931-32, pp. 129-30) report cultural and infection comparisons showing this fungus to be merely a strain of *H. sacchari*. Bourne (Fla. Agric. Exp. Sta. Bull. 267, p. 76, 1934) considers this fungus the primary cause of "ring spot" in Florida.

*Dematiaceae*. Conidiophores yellowish brown,  $70-380 \times 3.5-5 \mu$ ; conidia olive-green to brown, cylindrical, oblong or elliptical, often slightly curved, 3-10 septate,  $22-110 \times 9-21 \mu$ . (Mitra gives  $30-112 \times 11.5-18.5 \mu$ .) The fungus is highly variable, apparently existing as a number of different strains with saltation common. Leaf spots straw colored, red bordered, and often extending or coalescing into long streaks with indefinite halo. *Eye spot*.

Argentina, Australia, Brazil, Central America, Colombia, Cuba, Dominican Republic, Dutch East Indies, Dutch Guiana, Fiji, Florida, Georgia, Haiti, Hawaii, India, Jamaica, Lesser Antilles, Mauritius, Peru, Philippine Islands, Puerto Rico, Reunion, Singapore Island, Trinidad, Uganda, Union So. Africa, Venezuela.

HELMINTHOSPORIUM STENOSPILUM Drechsler, Phytopath. 18:135-6. 1928. Faris, Phytopath. 18:753-74. 1928.

*Dematiaceae*. Conidiophores dark olivaceous, erect, slightly bulbous at base,  $120-260 \mu$ ; conidia dark olivaceous, 3-12 septate,  $84 \times 17 \mu$ . Causes vandyke brown, linear, stripes with scant halos, up to  $20 \times 3$  mm. Brazil, Cuba, Dominican Republic, Formosa, Guam, Hawaii, India (?), Puerto Rico, Southern United States, Queensland. An ascigerous stage, *Ophiobolus stenospilus* Carp. (nom. nud.) was obtained by C. W. Carpenter in pure cultures originating from single spores of this *Helminthosporium*. (See Proc. Internat. Soc. Sugar Cane Tech. (4) Bull. 128:7, 1933.) Matsumoto and Yamamoto (Jour. Plant Prot. 23:9-14, 1936) also obtained an ascigerous stage and referred it to the more appropriate new genus *Cochliobolus*, as *C. stenospilus* (Carp.) Matsumoto and Yamamoto (nom. nud.). *Brown stripe*.

HELMINTHOSPORIUM TETRAMERA McKinney, U. S. Dept. Agric. Bull. 1347:33, fig. 5. 1925. Subramaniam, Indian Jour. Agr. Sci. 6:11-16. 1936.

*Dematiaceae*. Conidiophores dark olivaceous to brown, irregular; conidia borne in clusters of 2-50, tapering to rounded ends, chiefly 4-celled,  $20-40 \times 8.5-20 \mu$ . Cause of seedling disease. India.

HELMINTHOSPORIUM TURCICUM Pass., Boll. Comiz. Agr. Parmense 10:2. 1876. Sacc., Syll. Fungorum 4:420. 1886. Mitra, Mem. Dept. Agr. India (Bot. Ser.) 11:219-240. 1933.

*Dematiaceae*. Conidia 5-8 septate,  $85-92 \times 20-24 \mu$ . Usually as a parasite on leaves of *Zea mays*, but reported from India as "growing freely on sugarcane"; forming dirty straw-colored leaf spots in infection experiments.

HENDERSONIA SACCHARI Speg., Rev. Fac. Agron. y Vet. 2:241. 1896. Sacc., Syll. Fungorum 14:959. 1899.

*Phomaceae*. Pycnidia globose depressed in linear groups between leaf veins,  $100-120 \mu$ ; conidia linear fusoid, 3-septate, olivaceous,  $18-22 \times 3-4 \mu$ . Indefinite pale brown spots with reddish or yellow tints on leaves and sheaths. Argentina.

HENDERSONIA SACCHARICOLA (Averna Sacca) Trotter in Sacc., Syll. Fungorum 25:383. 1931. *Dendrophoma* (?) *saccharicola* Averna Sacca, Molestias Cryptog. da Cana de Assucar. São Paulo, p. 30, fig. 296. 1916. Averna Sacca, Bol. Agric. São Paulo 17:637-8, 1 fig. 1916.

*Phomaceae*. Pycnidia spherical, immersed in spots on leaves; sporophores



septate, branched; conidia olivaceous, cylindrical, 3-6 septate, ends obtuse,  $18-50 \times 8 \mu$ . On stalks. Brazil.

HENDERSONINA SACCHARI Butler, Mem. Dept. Agric. India (Bot. Ser.) 6:198, pls. I, III-V. 1913. Butler, Fungi and Disease in Plants, p. 388. 1918. Sacc., Syll. Fungorum 25:395. 1931.

*Phomaceae*. Pycnidia stromate, erumpent; conidia of two types, one straight or curved, ellipsoid or elongate, ends obtuse, continuous or 1-2 septate,  $15-24 \times 3.75-5 \mu$ ; second type filiform,  $20-60 \times .6-.2 \mu$ . Causing wilt of canes with internal red rot. Clements and Shear (The Genera of Fungi, p. 369, 1931) consider this a doubtful genus. Argentina, Ceylon, India, Mauritius, Philippine Islands. *Collar rot*.

HIMANTIA GUTTULIFERA Speg., Rev. Fac. Agron. y Vet. 2:257. 1896. Sacc., Syll. Fungorum 14:1196. 1899.

*Mycelia sterilia*. Yellow or rosy mycelial masses between leaf-sheaths, sterile; hyphae yellow, branched, septate, no crystals. On rotten leaves and sheaths. Argentina.

HIMANTIA SACCHARI Speg., Rev. Fac. Agron. y Vet. 2:257. 1896. Sacc., Syll. Fungorum 14:1195. 1899.

*Mycelia sterilia*. White mycelial masses in rotten culms, no crystals. Argentina.

HIMANTIA STELLIFERA Johnston, Jour. Dept. Agric. P. Rico 1:188, pls. XIX (fig. 2), XXI (figs. 1-4). 1917. Sacc., Syll. Fungorum 25:1005. 1931.

*Mycelia sterilia*. Mycelium sterile, white, cobwebby, ascending and binding together lower leaf-sheaths, penetrating roots; hyphae with clamp connections, bearing stellate crystals on short lateral branches. Possibly a form of *Odontia saccharicola* Burt (q.v.). *Stellate-crystal fungus*.

Argentina, Barbados, Brazil, British Guiana, Cuba, Dominican Republic, Hawaii, Jamaica, Java, Lesser Antilles, Madagascar, Natal, Puerto Rico, St. Croix, Trinidad, Union South Africa.

HORMIACTELLA SACCHARI Johnston, Jour. Dept. Agric. P. Rico 1:235, pls. XXV (fig. 4), XXX (figs. 1-5). 1917. Sacc., Syll. Fungorum 25:803-4. 1931.

*Dematiaceae*. Sori black, about 1 mm diam.; sterile hyphae erect, black, septate,  $500-900 \mu$ ; fertile hyphae branching,  $200-300 \mu$ ; conidia spherical, catenate,  $6 \mu$ . On dead leaves. Dominican Republic, Puerto Rico, Hawaii (?).

HORMISCIMUM SACCHARICOLUM Reichert, Engl. Bot. Jahrbuch. 56:718, pl. III (fig. 10). 1921.

*Dematiaceae*. Pustules effuse, confluent; conidia disc-shaped or tessellate, fuscous,  $5-13 \times 2.5-6 \mu$ . On dead stems of *Saccharum biflorum* (= *S. spontaneum*). Egypt.

HORMODENDRON CLADOSPORIOIDES (Fres.) Sacc., Michelia 2:148. 1880. Sacc., Syll. Fungorum 4:310. 1886.

*Dematiaceae*. Conidia lemon-shaped, continuous or rarely 2-septate, olivaceous,  $4.5-6 \times 3 \mu$ . Olivaceous mold on sugar. Union South Africa.

HYDNUM SACCHARI Sprengel, K. Svenska Vet. Akad. Handl. 1820:51. 1820. Sacc., Syll. Fungorum 6:460. 1888.

*Hydaceae*. Hymenium yellow, effuse, resupinate. Not a *Hydnum*, as that genus is now understood. On dead cane stalks and leaves. Guadeloupe, Puerto Rico.

*Hypochnus centrifugus* (Lev.) Tul. See *Sclerotium rolfsii* Sacc.

HYPOCHNUS SACCHARI Speng., Rev. Fac. Agron. y Vet. 2:227. 1896. Sacc., Syll. Fungorum 14:226. 1899.

*Thelephoraceae*. Mycelium arachnoid, white (or rosy); spores ovate, hyaline,  $10-12 \times 4-5 \mu$ . Not *Hypochnus*, as that genus is now understood. On unfolding leaves of canes attacked by "Polvillo." Argentina, Jamaica (?). A Cuban report of this species was later referred to *Odontia sacchari* Burt.

HYPOCHNUS (CORTICIUM) SASAKII Shirai, Bot. Mag. Tokyo 20:319-23. 1906. Butler, Fungi and Disease in Plants, p. 410. 1918. Sacc., Syll. Fungorum 21:415. 1912. Subramaniam, Imp. Council Agr. Res. Misc. Bull. 10:22-23. 1936.

*Thelephoraceae*. Sclerotia soft, white, becoming brown and hard, variable in size and shape; hymenium dusty white; basidia hyaline, obovate,  $10-16 \times 8-9 \mu$ ; spores hyaline, obovate or slightly cylindrical, more or less flattened,  $6-10 \times 4-7 \mu$ . More properly a *Corticium*. Causes a disease known in Formosa as "Kohan-hyô." On leaf blades and sheaths and stalks, "characterized by yellowish-brown to grayish-brown patches enclosed by a purplish-brown irregular band, somewhat resembling the markings of the fur of a tiger after which the Japanese name was given." This is apparently the "banded sclerotial disease" or "*djamocr oepas*" reported as due to *Sclerotium* sp. See Butler (l. c.); Wakker and Went, Ziekten Suikerriet op Java, p. 134-40, pl. 16 (col.), 1898; and Matsumoto, Yamamoto and Hirane, Jour. Soc. Trop. Agric. Formosa 5:332-5, 4 figs. 1933. Australia, Dutch East Indies, Formosa, India, Philippine Islands, Siam. See also *Rhizoctonia grisea*.

*Hypocrea gelatinosa* (Tode) Fr. See *Chromocrea gelatinosa* (Tode) Seaver

HYPOCREA RUFA (Pers.) Fr., Summa Veg. Scand., p. 383. 1849. Sacc., Syll. Fungorum 2:520. 1883. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:213. 1917.

*Hypocreaceae*. Stromata brick-red, subhemispheric to patellate, surfaces roughened by necks of perithecia, 2 mm to 1 cm diam.; perithecia immersed, globose, 175-200  $\mu$  diam.; spores globose, hyaline, 3-4  $\mu$  diam. On dead cane stalks. Colombia, Puerto Rico.

HYPOCREA SACCHARALIS Racib., Parasit. Algen u. Pilze Javas III, pp. 21-22, 43. 1900. Sacc., Syll. Fungorum 16:583-4. 1902.

*Hypocreaceae*. Stromata brown, circular, 2-3 mm diam.; perithecia immersed, oval, 220-240  $\mu$  high, 120-150  $\mu$  wide; asci 8-, finally 16-spored; spores globose or ovate, 2-3.5  $\mu$  diam. On living leaf-sheaths. Java.

*HYPOCREA SACCHARI* Went, Arch. v.d. Java Suikerind. 1:455, pl. VII (figs. 8-10). 1893. Sacc., Syll. Fungorum 11:362. 1895. Wakker and Went, Ziekten Suikerriet op Java, p. 193. 1898.

*Hypocreaceae*. Stromata pulvinate-depressed, pale fuscous, 2-4 mm diam.; spores 2-celled (?), smoky olive; upper cell globose, 4  $\mu$  diam.; lower oblong, 6  $\times$  4  $\mu$ . On leaf blades and sheaths, killing seedlings. Java. Went includes a conidial stage, *Verticillium sacchari* Went.

*Ithyphallus celebicus* P. Henn. See *Ithyphallus rubicundus* (Bosc) Fischer

*Ithyphallus coralloides* Cobb See *Ithyphallus rubicundus* (Bosc) Fischer

*ITHYPHALLUS RUBICUNDUS* (Bosc) Fischer, Jahrb. Bot. Gart. u. Mus. Berlin 4:50. 1886. Sacc., Syll. Fungorum 7:11. 1888. Cunningham, Proc. Linn. Soc. New So. Wales 55:10-11. 1931. *Phallus rubicundus* (Bosc) Fr., Syst. Myc. 2:284. 1822. *Phallus celebicus* P. Henn., Monsunia 1:21. 1899. *Ithyphallus celebicus* (P. Henn.) Sacc. and Syd. in Sacc., Syll. Fungorum 16:225. 1902. *Ithyphallus coralloides* Cobb, Hawaii. Sugar Plant. Exp. Sta. (Path. and Phys. Ser.) Bull. 5:208, figs. 97-99. 1906.

*Phallaceae*. Receptacle variable, fusiform or cylindrical, up to 18 cm tall and 3 cm diam., scarlet; pileus conical, scarlet, slightly rugulose; gleba external, fetid, olivaceous; spores smooth, elliptical, 3.5-5  $\times$  1.5-2  $\mu$ . Associated with root disease, and on cane trash. Saprophytic. Hawaii, Java. *Stink-horn*.

*LACHNEA CUBENSIS* (Berk. and Curt.) Sacc., Syll. Fungorum 8:176. 1889. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:215. 1917.

*Pezizaceae*. Cups scarlet, with rigid brown marginal setae; spores broadly elliptical, 18-20  $\times$  11  $\mu$ . On dead cane leaves. Puerto Rico.

*Lasiodiplodia theobromae* (Pat.) Griff. and Maubl. See *Physalospora rhodina* (Berk. and Curt.) Cke.

*LASIOSPHAERIA* sp.

*Sphaeriaceae*. An undetermined species on dead canes. Puerto Rico.

*LATERNEA COLUMNATA* (Bosc) Nees See *Clathrus columnatus* Bosc

*LEEINA PHILIPPINENSIS* Petr., Ann. Myc. 21:315. 1923.

*Phomaceae*. Pycnidia in subepidermal stromata, spherical, 200-350  $\mu$  diam.; conidia hyaline, 1-celled, 2-3  $\times$  .75-1  $\mu$ ; conidiophores 6-11  $\mu$  long. On dead leaves and stems. India, Philippine Islands. Petrak suggests that *Cytospora sacchari* Butl. belongs here and adds "Jedenfalls scheint Butler's Pilze keine *Cytospora* zu sein." Clements and Shear (Genera of Fungi, p. 370, 1931) place the genus in "Genera dubia."

*LENTINUS CRINITUS* (L.) Fr., Syst. Orbis Veg., p. 77. 1825. Sacc., Syll. Fungorum 5:576. 1887.

*Agaricaceae*. Pileus convex to infundibuliform, 4-7 cm broad; surface pale fawn-colored to dark reddish-brown, covered with stiff squamose dark fuscous hairs; lamellae decurrent; stipe central, glabrous, silky at apex, 2-4 cm long, 3 mm thick. On dead cane. Puerto Rico.

*LEPIOTA LYCOPERDINEA* Speg., Anal. Mus. Nac. Buenos Aires (2) 3:87. 1899. Sacc., Syll. Fungorum 16:6. 1902.

*Agaricaceae*. Growing in cane fields. Argentina.

## LEPTOSPHERIA sp.

*Sphaeriaceae*. An undetermined species associated with "Giant ring spot." Hawaii. On leaves. Formosa.

LEPTOSPHERIA SACCHARI v. Breda de Haan, Med. v. het Proefsta. v. Zuikerriet in West-Java 3:25-28. 1892. Sacc., Syll. Fungorum 11:324. 1895. Spegazzini, Rev. Fac. Agron. y Vet. 2:232. 1896. Wakker and Went, Ziekten Suikerriet op Java, pp. 149-153, pl. XX (col.). 1898. Butler, Mem. Dept. Agric. India (Bot. Ser.) 1:45-47, pl. 6 (figs. 22-25). 1906. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:203, pls. XXV (fig. 1), XXXI (figs. 5, 6). 1917. Bourne, Fla. Agric. Exp. Sta. Bull. 267, 76 pp., 23 figs. 1934.

*Sphaeriaceae*. Perithecia 120-150  $\mu$  diam., black, subepidermal, paraphysate; spores 2-3 septate,  $25 \times 10 \mu$ . On living leaves, producing numerous oval (5-10 mm wide  $\times$  7-15 mm long), dull gray to straw-colored spots with definite red to red-brown margins.

Bourne (l.c.) considers *L. sacchari* a saprophyte merely associated with *Helminthosporium ocellum* Faris, "the primary cause of the disease." A conidial stage (a *Dematium*?) was suggested by de Haan, later assigned to *Acrothecium* by Wakker and Went (l.c.) who disclaimed its connection with *Leptosphaeria*. Conidia "appear to belong to *Acrothecium lunatum* group"—Mason. Van der Bijl (Jour. Dept. Agric. So. Africa 2:123, 1921) mentions a *Phoma* as a stage of *Leptosphaeria sacchari*. Bourne (l.c.) obtained a pycnidial stage in pure cultures originating from single ascospores of the *Leptosphaeria* and refers this to *Phyllosticta saccharicola* P. Henn. Matsumoto and Yamamoto (Jour. Plant. Prot. 23:9-14, 1936) substantiate the genetic connection with a species of *Phyllosticta*.

*Ring spot.*

Andaman Islands, Antigua, Argentina, Australia, Barbados, Belgian Congo, Brazil, British Guiana, Burma, Central America, Ceylon, China, Colombia, Cuba, Dominican Republic, Dutch Guiana, Fiji, Formosa, Gold Coast, Guadeloupe, Haiti, Hawaii, Honduras, India, Indo-China, Jamaica, Japan, Java, Kenya, Lesser Antilles, Madagascar, Mauritius, Mexico, Peru, Philippine Islands, Puerto Rico, Reunion, Sierra Leone, Southern United States, Sumatra, Surinam, Tanganyika, Trinidad, Uganda, Union So. Africa, Venezuela.

*Leptosphaeria sacchari* Speg. See *Leptosphaeria spegazzinii* Sacc. and Syd.

LEPTOSPHERIA SACCHARICOLA P. Henn., Hedw. 39:79 (Beibl.). 1900. Sacc., Syll. Fungorum 16:516-17. 1902.

*Sphaeriaceae*. Perithecia membranous, black, subglobose, 100-120  $\mu$  diam.; spores brown, 3-4 septate,  $15-19 \times 4 \mu$ . On living leaves producing pale, oblong, brown bordered spots. Brazil.

LEPTOSPHERIA SPEGAZZINII Sacc and Syd in Sacc., Syll. Fungorum 14:570. 1899. *Leptosphaeria sacchari* Speg., Rev. Fac. Agron. y Vet. 2:232. 1896.

*Sphaeriaceae*. Perithecia amphigenous, immersed, 120-140  $\mu$  diam.; spores fusoid, acute at ends, 3-septate, constricted at septae,  $25 \times 5-6 \mu$ . On dead and dying leaves producing indefinite pale spots. Argentina.

LEPTOSPHERIA SPEGAZZINII Sacc. and Syd. var. MINOR Speg., Anal. Mus. Nac. Buenos Aires 19:383. 1909. Sacc., Syll. Fungorum 22:233. 1913.

*Sphaeriaceae*. Perithecia 100-120  $\mu$  diam.; spores 16-18  $\times$  4-5  $\mu$ . On culms. Argentina.

LEPTOSPHERIA TUCUMANENSIS Speg., Rev. Fac. Agron. y Vet. 2:232. 1896. Sacc., Syll. Fungorum 14:569-70. 1899.

*Sphaeriaceae*. Spores obtuse at ends, 5-7 septate, fusoid, 18-20  $\times$  3-4  $\mu$ . On culms. Argentina.

LEUCONOSTOC MESENTERIOIDES (Cienk.) v. Tiegh., Ann. des Sci. Nat., ser. VI, 7:180. 1878. Spegazzini, Rev. Fac. Agron. y Vet. 2:239. 1896. Sacc., Syll. Fungorum 8:1052. 1889. Bergey's Man. Deter. Bact., ed. 1, p. 45. 1923.

*Coccaceae*. Organism spherical, .9-1.2  $\mu$  diam., in pairs or chains which in sugar solutions are surrounded by a thick, gelatinous, colorless membrane. Produces slime in sugar solutions in sugar mills and refineries. Argentina, Java. Zopf (Beitr. z. Physiol. u. Morph. nied. Organismen, heft 1:1-28, 1892) suggests that the Javanese organism be considered as var. *indica*, because of minor differences in physiological response. See also Winter, Arch. Java Suikerrind. 1:282-288. 1893.

*Ligniera vascularum* (Matz) Cook See *Plasmodiophora vascularum* Matz

LINOSPORA SACCHARI Avena Sacca., Bol. Agric. Sao Paulo 17:614, 1 fig. 1916. Sacc., Syll. Fungorum 24:1061-2. 1928.

*Sphaeriaceae*. Perithecia globose, immersed; spores filiform, hyaline, continuous, 108-120  $\times$  3  $\mu$ . On culms. Argentina, United States.

*Lisca australis* Speg. var. *sacchari* Speg. See *Gibberella fujikuroi* (Saw.) Wr. LOPHODERMIIUM sp.

*Hysteriaceae*. An unnamed species on dead leaf-sheaths. Puerto Rico.

LOPHODERMIIUM SACCHARI Lyon, Hawaii. Plant. Record 9:600-601; Bull. Exp. Sta. Hawaii. Sugar Plant. Assoc., Bot. Ser., 3:76, 3 figs. 1921. Sacc., Syll. Fungorum 24:1126. 1928.

*Hysteriaceae*. Perithecia black, erumpent, 1-3, rarely 4 mm long, .25-.5 mm wide; paraphyses bulb-tipped, some branched; spores hyaline, acicular, 48-55  $\times$  1-1.5  $\mu$ . On mid-ribs and leaf-sheaths of dead leaves. Hawaii.

LYCOGALA EPIDENDRUM (L.) Fr., Syst. Myc. 3:80. 1829. Macbride and Martin, The Myxomycetes, p. 243. 1934.

*Lycogalaceae*. Aethalia depressed, spherical, olivaceous or blackish, 3-10 mm diam.; spores minutely reticulate, 5-6  $\mu$  diam. On trash. Dominican Republic, Puerto Rico.

LYCOPERDON ALBINUM Cke., Jour. Roy. Micro. Soc. 1887:723. 1887. Sacc., Syll. Fungorum 7:487. 1888.

*Lycoperdaceae*. Fruiting bodies globose, white, not over 1 cm diam.; spores smooth, globose, 3  $\mu$ . On very rotten cane trash. Puerto Rico.

LYCOPERDON PUSILLUM Batsch, Elen. Fung. 3:124, pl. XLI (fig. 228). 1789. Sacc., Syll. Fungorum 7:487. 1888.

*Lycoperdaceae*. Fruiting bodies 6-16 mm diam.; spores ochraceous olivaceous, globose, 4  $\mu$ . On cane trash. Puerto Rico.

**LYCOPERDON PYRIFORME** Schaeff., Icon. Fung., p. 128, tab. 185. 1763. Sacc., Syll. Fungorum 7:117. 1888.

*Lycoperdaceae.* Plants pyriforme, up to 4.5 cm broad and high, red-brown when dry; cortex of minute warts and granules, rough to touch; spores spherical, smooth, deep olive-brown, 3.8-4.3  $\mu$ . On cane trash. Puerto Rico.

**MACROPHOMA SACCHARI** (Cke.) Berl. and Vogl., Atti Soc. Ven.-Trentina Sci. Nat. 10:186. 1886. *Sphaeropsis sacchari* Cke., Grev. 12:23. 1883. *Phoma sacchari* (Cke.) Sacc., Syll. Fungorum 3:166. 1884.

*Phomaceae.* Pycnidia black, subglobose, erumpent; conidia hyaline, lanceolate, 32-42  $\times$  12  $\mu$ . On dead culms. Georgia (U.S.A.), Italy. Cobb tentatively used the binomial (*Phoma sacchari*) for a fungus associated with what he called "cane freckle." New So. Wales.

**MACROPHOMINA PHASEOLI** (Maubl.) Ashby, Trans. Brit. Myc. Soc. 12:145. 1927. *Sclerotium bataticola* Taub., Phytopath. 3:161-4. 1913. *Rhizoctonia bataticola* (Taub.) Butler ex Britton-Jones, Min. Agric. Egypt, Tech. and Sci. Ser. Bull. 49:65. 1925.

*Phomaceae.* Minute black sclerotia in and on roots; pycnidia black, immersed to erumpent, globose, 100-200  $\mu$  diam.; conidia hyaline, 1-celled, elliptical, or oval, 16-29  $\times$  6-9  $\mu$ . On roots and base of stalks. Egypt, India.

**MACROSPORIUM GRAMINUM** Cke. in Ravenel and Cook, Fungi Amer. Exsic., No. 606, 1882, and Grevillea 17:66. 1889. Sacc., Syll. Fungorum 10:677. 1892.

*Dematiaceae.* Conidia fuscous, 4-5 septate, muriform, 60-70  $\times$  22  $\mu$ . An *Alternaria* in the *A. tenuis* group of Elliott (Amer. Jour. Bot. 4:447. 1917). On dead leaves. Hawaii, New So. Wales, Tasmania.

**MARASMIUS** spp.

*Agaricaceae.* Unnamed species occurring on cane trash or associated with root disease, etc., many of which are probably *M. sacchari*. Argentina, Barbados, British Guiana, Cuba, Indo-China, Java, Mauritius, Peru, Philippine Islands, Queensland, St. Croix, Trinidad, Union So. Africa.

**MARASMIUS BAMBUSINUS** Fr., Linnaea 5:507. 1830. Sacc., Syll. Fungorum 5:543. 1887.

*Agaricaceae.* A small white species. On dead canes. Cuba.

**MARASMIUS BORINQUENSIS** Stevenson, Jour. Dept. Agric. P. Rico 1:218. 1917. Sacc., Syll. Fungorum 23:161. 1917.

*Agaricaceae.* Pileus up to 3 mm broad, radiate-sulcate, glabrous, white, yellow on drying, lamellae few, distant, white; stipe 2-6 mm long, concolorous; spores elliptical-ovoid, 7  $\times$  5  $\mu$ . On cane trash. Puerto Rico.

**MARASMIUS HIORAMI** Murrill, No. Amer. Fl. 9:256. 1915. Sacc., Syll. Fungorum 23:151. 1925.

*Agaricaceae.* Pileus 3-4 mm broad; surface bay, glabrous, radiate-sulcate; gills broad, adnate; stipe fuliginous to black, smooth, polished, 2-3 cm long. On cane trash. Puerto Rico.

**MARASMIUS PLICATUS** Wakker in Wakker and Went, Ziekten Suikerriet op Java, p. 195. 1898. Sacc., Syll. Fungorum 14:115. 1899.

*Agaricaceae.* Stipe central, filiform; pileus broadly campanulate, plicate, brown; lamellae about 7; spores ovoid, hyaline, with rounded apex, 6-8  $\times$  4-5  $\mu$ .

On dead leaves. Java, Philippine Islands. New World reports of the occurrence of this species associated with root rot should be referred apparently to *M. stenophyllus* (Johnston, Mycologia 8:115. 1916.).

**MARASMIUS SACCHARI** Wakker, Arch. v. d. Java Suikerind. 3:577-9, 5 figs. 1895. Centralbl. f. Bakt. u. Par. II, 2:44. 1896. Wakker and Went, Ziekten Suikerriet op Java, pp. 49-63, pl. V. 1898. Sacc., Syll. Fungorum 14:115. 1899. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:183-7, pls. XX (fig. 1), XXVI (figs. 9-10). 1917.

*Agaricaceae*. Pileus campanulate, white, finally sordid white, up to 15 mm diam.; lamellae white, simple or bifurcate; stipe central, white, 15 mm long; spores hyaline, irregularly oblong, attenuate at both ends,  $16-20 \times 4-5 \mu$ . On dead and dying cane. Associated with the root disease complex.

American Virgin Islands, Antigua, Australia, Barbados, Brazil, British Guiana, British Virgin Islands, Colombia, Cuba, Dominica, Dominican Republic, Fiji, Formosa, Granada, Guadeloupe, Hawaii, India, Jamaica, Java, Martinique, Mauritius, Montserrat, Nevis, Philippine Islands, Puerto Rico, St. Kitts, St. Lucia, St. Vincent, Trinidad.

**MARASMIUS SACCHARI** Wakker var. **HAWAIIENSIS** Cobb, Exp. Sta. Hawaii. Sugar Plant. Assoc. Bull. (Path. and Phys. Ser.) 5:230, pl. VII. 1906. Sacc., Syll. Fungorum 23:162. 1925.

*Agaricaceae*. Spores shorter ( $12-16 \times 4-5 \mu$ ) than in the species. Associated with root rot. Hawaii. Usually considered synonymous with the species.

*Marasmius semiustus* Berk. and Curt. See *Marasmius stenophyllus* Mont.

**MARASMIUS STENOPHYLLUS** Mont., Ann. Sci. Nat. IV, 1:116. 1854. Sacc., Syll. Fungorum 5:549. 1887. Murrill, N. Amer. Flora 9:262. 1916. *Marasmius semiustus* Berk. and Curt., Jour. Linn. Soc. 10:296. 1868.

*Agaricaceae*. Pileus membranaceous, convex-plan, 5-7 mm wide, pale yellowish to reddish tan; lamellae adnate; stipe tough, solid or spongy, central, or excentric with age, 8-15 mm tall, 1-2 mm thick; spores ellipsoid, smooth, hyaline,  $7-9 \times 5-6 \mu$ . Associated with root rot. Cuba, Louisiana, Mississippi, Texas, Trinidad. Puerto Rico report not confirmed. New World reports of *M. plicatus* are referred to this species.

**MARASMIUS SYNODICUS** (Kze.) Fr., Epicr. Myc., p. 381. 1838. Sacc., Syll. Fungorum 5:533. 1887. Murrill, No. Amer. Flora 9:257. 1916.

*Agaricaceae*. Pileus convex to expanded, 6-10 mm, white or pallid, sulcate; stipe whitish, 1-2 cm long, 1 mm thick; spores smooth, ellipsoid,  $6 \times 4 \mu$ . On cane trash. Puerto Rico.

**MARSONIA** sp.

*Melanconiaceae*. An unnamed species on midribs of dead leaves. Puerto Rico.

*Melanconium iliau* Lyon See *Gnomonia iliau* Lyon

*Melanconium lineolatum* Sacc. See *Papularia vinosa* (Berk. and Curt.) Mason

**MELANCONIUM SACCHARI** Massee ap. Speg., Rev. Fac. Agron. y Vet. 2:242. 1896. Sacc., Syll. Fungorum 14:1019. 1899. Op. cit. 25:582. 1931. *Strumella*

*sacchari* Cke., Grev. 19:45. 1890. *Trullula sacchari* Ell. and Ever., Jour. Inst. Jamaica 1:159. 1892. *Coniothyrium sacchari* (Mass.) Prill. and Delacr., Bull. Soc. Myc. France 13:113. 1897. Delacroix, Malad. Plant Cult. dans Pays Chauds, p. 528. 1911. *Microsphaeropsis bakeri* Syd., Ann. Myc. 14:369. 1916. Sacc., Syll. Fungorum 25:260. 1931. *Haplosporella melanconioides* Sacc., Atti dell'Accad. Ven.-Trent. Istrian. 10:73. 1917. Sacc., Syll. Fungorum 25:267. 1931. *Pleocyta sacchari* (Mass.) Petr. and Syd., Repert. Spec. Nov. Regni Veg. 42:455-6. 1927.

*Melanconiaceae*. Sporodochia subepidermal; conidiophores hyaline, 10-12  $\times$  1.5-2  $\mu$ ; conidia long, cirrhone, olive-brown, cylindrical, 9-14  $\times$  2.7-3.5  $\mu$ .

*Rind-disease*.

Andaman Islands, Antigua, Argentina, Barbados, Borneo, Brazil, British Guiana, Central America, China, Colombia, Cuba, Dominican Republic, Egypt, Fiji, Formosa, Guadeloupe, Hawaii, India, Indo-China, Jamaica, Java, Madagascar, Malaya, Martinique, Mauritius, Mexico, Nevis, New So. Wales, Paraguay, Peru, Philippine Islands, Portugal, Puerto Rico, Queensland, Reunion, St. Kitts, St. Lucia, St. Vincent, South China, Southern United States, Tahiti, Trinidad, Uganda, Union So. Africa. On *Saccharum spontaneum*, Philippine Islands, Siam.

Massee describes *Trichosphaeria sacchari* (Kew Bull. Misc. Infor. 1893:149 and Ann. Bot. 7:515, pl. XXVII, 1893) as the perfect stage, but his work has never been confirmed. Petrak and Sydow studied Massee's specimen and state "eine *Papularia*-artige Form ist." Massee's plate illustrates micro- and macroconidia (endogenous) of *Thielaviopsis*. Howard (Ann. Bot. 15:683-701. 1901) erroneously reports *Melanconium* and *Diplodia cacaoicola* as forms of the same fungus. *Microdiplodia melaspora* (q. v.) under one or another of its names has been commonly considered synonymous with this *Melanconium*.

*Melanconium saccharinum* Penz. and Sacc. See *Papularia vinosa* (Berk. and Curt.) Mason

MELANOSPORA GLOBOSA Berl., Malpighia 5:409, pls. XXIX., XXX. 1891. Sacc., Syll. Fungorum 11:356. 1895. Spegazzini, Rev. Fac. Agron. y Vet. 2:234. 1896.

*Hypocreaceae*. Perithecia superficial, globose-ovoid, 250-280  $\mu$  diam.; spores lemon-shaped, 18-21  $\times$  16-17  $\mu$ . On dead leaves and culms. Argentina.

MELIOLA sp.

*Perisporiaceae*. All reports of *Meliola* spp. as sooty molds are more properly *Capnodium* or related forms. *Meliola capnodium* ex Cook, Cong. Int. Soc. Sugar Cane Tech. Proc. 4, Bull. 128:4, 1932, is apparently in the same category.

MELIOLA ARUNDINIS Pat., Jour. de Bot. 11:348. 1897. Sacc., Syll. Fungorum 14:473. 1899. Stevens, Ann. Myc. 26:182. 1928.

*Perisporiaceae*. Perithecia 150-200  $\mu$  diam.; setae erect, 3-4 branched at tip, about 200  $\mu$  tall; spores 4-septate, 40-55  $\times$  20  $\mu$ ; capitate hyphopodia alternate. Black, more or less circular, superficial areas on living leaves of *Saccharum* spp. China, India, Philippine Islands.



MELIOLA HERCULES v. Höh. Sitzber. K. Akad. Wiss. Wien Math. Natur. Kl. 118: 316. 1909. Sacc., Syll. Fungorum 22:57. 1913.

*Perisporiaceae*. On leaves. *S. spontaneum*. Java.

MELIOLA PANICI Earle, Muhlenbergia 1:12. 1901. Sacc., Syll. Fungorum 17: 550. 1905.

*Perisporiaceae*. On leaves. *S. spontaneum*. Philippine Islands.

MELIOLA SACCHARI Syd., Ann. Myc. 12:548. 1914. Sacc., Syll. Fungorum 24: 294. 1926. Stevens, Ann. Myc. 26:184. 1928.

*Perisporiaceae*. Perithecia 150-200  $\mu$  diam.; setae erect, irregularly 2-6 branched at tip, 175-400  $\mu$  tall; spores 4-septate,  $40-48 \times 14-18 \mu$ ; hyphopodia opposite. Black, superficial, fungus patches on living leaves of *S. officinarum*, India and *S. spontaneum*, Philippine Islands. Stevens suggests "perhaps merely a variety of *M. arundinis* with somewhat longer setae."

MERULIUS BYSSOIDES Burt, Ann. Mo. Bot. Garden 4:358, pl. XXII (fig. 35). 1917. Sacc., Syll. Fungorum 23:462. 1925.

*Polyporaceae*. Hymenium dry, effused, dresden-brown, rugose-porose, pores shallow (2-4 per mm); spores even, deep olive-buff,  $4.5-6 \times 3.5-4.5 \mu$ . On cane trash and soil. Puerto Rico.

METASPHERIA SACCHARICOLA Speg., Ann. Mus. Nac. Buenos Aires (3) 10:376. 1909. Sacc., Syll. Fungorum 22:199-200. 1913.

*Sphaeriaceae*. Perithecia erumpent or superficial, 150-180  $\mu$  diam.; paraphyses filiform; spores elongate-fusoid, dilutely hyaline, 7-septate,  $45-50 \times 7-8 \mu$ . On rotten culms. Argentina.

METASPHERIA USTERI Speg., Rev. Mus. LaPlata 15:23. 1908. Sacc., Syll. Fungorum 22:198-9. 1913.

*Sphaeriaceae*. Perithecia amphigenous, 90-120  $\mu$  diam.; spores hyaline, sub-fusiform, 5-septate,  $20 \times 4 \mu$ . Spots amphigenous on dying leaves, 10-30  $\times$  2-4 mm. Argentina.

MICRODIPLODIA MELASPORA (Berk.) Griff. and Maubl., Bull. Soc. Myc. France 25:55. 1909. Sacc., Syll. Fungorum 22:1006. 1913. *Darluca melasporea* Berk. in Cooke, Nuovo Giorn. Bot. Ital, 10:26. 1878. *Coniothyrium melasporea* (Berk.) Sacc., Syll. Fungorum 3:319. 1884. *Microdiplodia melasporea* (Berk.) Petr. and Syd., Ann. Myc. 22:341. 1924.

*Phomaceae*. Conidia 2-celled (rarely one),  $6-10 \times 4.5-6 \mu$ . On dead culms. Philippine Islands, Portugal, Puerto Rico (erroneously referred in Cooke's note to Queensland), Venezuela. This fungus has been generally referred to *Melanconium sacchari*, but Delacroix (Bull. Soc. Myc. Fr. 13:113, 1897) and Petrak and Sydow (Repert. Spec. Noc. Regni Veg. 42:455, 1927) studied the type and consider the two distinct. Chardon and Toro (Monog. Univ. P. Rico B 2:226, 1934) refer here a Venezuelan specimen, reporting, however, 1-celled conidia.

*Microsphaeropsis bakeri* Syd. See *Melanconium sacchari* Mass.

MICROSPIRA NORTHII Carpenter and Bomonti. Hawaii. Planters' Rec. 25:179-180, pl. I. 1921.

*Spirillaceae*. Organism a straight to curved rod, variable,  $2.5-8.0 \times 0.75-1.5 \mu$ ; motile with three to ten or more elongated, peritrichiate flagella; spores

ovoid, in middle of rods,  $2.5 \times 3.0 \mu$ ; gas liberating, non-gum forming; thermophilic, causing deterioration of hot juices in factory. Hawaii.

**MICROTYPHA SACCHARICOLA** Spég., Anal. Mus. Nac. Buenos Aires (3) 13:342. 1910. Sacc., Syll. Fungorum 22:1352. 1913.

*Dematiaceae*. Fertile hyphae gregarious, straight or subcircinate; conidia ellipsoid, smooth, rounded at both ends,  $5.6 \times 3.4 \mu$ , borne in dense cylindrical masses (Typha-like). On rotten culms. Argentina.

**MONASCUS PURPUREUS** Went, Ann. Sci. Nat. (8) 1:1-18, illus. 1895. Sacc., Syll. Fungorum 14:825. 1899.

*Monascaceae*. Forming purple colonies; sporangia globose,  $30-75 \mu$  diam., polysporous; spores angular then spherical, purple,  $5-6.5 \mu$  diam.; conidia in short chains, globose, purple. On spoiled sugar. Louisiana.

**MONILIA FUSCA** Browne, Jour. Ind. Eng. Chem. 10:178-90. 1918. Guilliermond and Tanner, The Yeasts, p. 378, 2 figs. 1920.

*Moniliaceae*. Colonies greenish brown, otherwise as with *M. nigra*. On Cuban raw sugar.

**MONILIA JAVANICA** Went and Prin.-Geerligs, Arch. Java-Suikerindus. 2:542-43, pl. III (fig. 9). 1894. Sacc., Syll. Fungorum 11:589. 1895.

*Moniliaceae*. Hyphae forming bundles, budding freely at ends and on lateral branches; conidia ellipsoid, hyaline,  $5-8 \mu$  long. Concerned in production of alcoholic drink "arak" from final molasses. Java.

**MONILIA NIGRA** Browne, Jour. Ind. Eng. Chem. 10:178-90. 1918. Guilliermond and Tanner, The Yeasts, p. 376-7, 2 figs. 1920.

*Moniliaceae*. Colonies black; hyphae budding freely, composed of chains of cells, strongly constricted at septa. On Cuban raw sugar.

*Monilia sitophila* (Mont.) Sacc. See *Neurospora sitophila* Shear and Dodge.

**MUCOR** spp.

*Mucoraceae*. Undetermined species associated with root-rot (secondary), on cane trash, etc. Louisiana.

**MYCORRHIZA**

Ciferri (Phytopath. 18:249-61, 1928) reports a Phycomycetous endophyte in roots. Dominican Republic. Costantin (Ann. Sci. Nat. (Bot. Ser.) 10: 299-364. 1927) opines that Seréh (in Java) is due to absence of mycorrhizal fungi and loss of hereditary vigor.

**MYCOSPHAERELLA**

*Sphaerella* as a fungus name is a homonym of *Sphaerella*, an algal genus, hence species in the former genus have been or should be transferred to *Mycosphaerella*. To avoid making new combinations, however, in this publication, the four species on cane are treated under *Sphaerella*.

*Mycosphaerella striatiformans* Cobb See *Sphaerella striatiformans* (Cobb) Sacc. and Trott.

**MYRIOGENOSPORA ACICULISPORAE** Vizioli, Bol. Agric. São Paulo 27:60-69, 3 pls. 1926. Diehl, Phytopath. 24:677. 1934.

*Dothidiaceae*. Stromatic masses of hyphae on leaves (often binding unfolding leaves together) in which loculate perithecia appear,  $250-380 \times 200-300 \mu$ ,

delimited by a zone of dark tissue, ostiolate; asci fusiform,  $210-250 \times 12-16 \mu$ , multispored; spores  $18-25 \times 1.5 \mu$ . Argentina, Brazil.

*MYROTHECIUM VERRUCARIA* (Alb. and Schw.) Ditm. in Sturm, Deutsch.-Fl. 1:7. 1816. Sacc., Syll. Fungorum 4:750. 1886. Spegazzini, Rev. Fac. Agron. y Vet. 2:256. 1896.

*Tuberculariaceae*. Sporodochia black, subcircular, with white villose margins, 1-2 mm diam.; conidia ovate, olivaceous fuscous,  $8-10 \times 3-5 \mu$ . On dead and dying leaf-sheaths. Argentina, Puerto Rico.

*NAUCORIA SACCHARI* Murrill, Mycologia 4:79. 1912. Sacc., Syll. Fungorum 23:272. 1925.

*Agaricaceae*. On dead roots. Jamaica.

*NAUCORIA SUBORBICULARIS* (Bull.) Fr., Hymen. Succiae 1:376. 1857. Sacc., Syll. Fungorum 5:844. 1887.

*Agaricaceae*. On rotting trash. Argentina.

*NECTRIA* spp.

*Hypocreaceae*. Undetermined species on dead and dying canes. Brazil, Florida, Hawaii, Puerto Rico.

*NECTRIA FLAVOCILIATA* Seaver, Mycologia 1:54, pl. V (fig. 11). 1909. Sacc., Syll. Fungorum 22:471. 1913.

*Hypocreaceae*. Perithecia gregarious, subglobose, clothed with golden or sulphur-yellow clavate hairs,  $250-300 \mu$  diam.; spores fusoid, 1-septate, hyaline,  $8-12 \times 2.5-3 \mu$ . On dead stalks. Puerto Rico.

*NECTRIA LAURENTIANA* Marchal, Bull. Soc. Belge de Microsc. 20:261, pl. VII (fig. 2). 1894. Sacc., Syll. Fungorum 11:358. 1895. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:213-14, pl. XXVII (figs. 21-23). 1917.

*Hypocreaceae*. Perithecia stromatic, rugose; asci  $60-70 \times 7-8 \mu$ ; spores  $12-13 \times 4-5 \mu$ , with *Fusarium* conidial stage. On rotten stalks. Belgian Congo, Dominican Republic, Puerto Rico. Transferred by Seaver and Chardon (Sci. Survey P. Rico 8:42. 1926) to *Creonectria*.

*NECTRIA SACCHARICOLA* Speg., Rev. Fac. Agron. y Vet. 2:234. 1896. Sacc., Syll. Fungorum 14:634. 1899.

*Hypocreaceae*. Perithecia superficial, gregarious, dull yellow or ochraceous,  $150-180 \mu$  diam.; spores  $10-12 \times 3-4 \mu$ . On rotten stalks. Argentina.

*Nematosporangium arrhenomanes* (Drechsler) Sideris The genus *Nematosporangium* (Schröter, 1893) appears synonymous with the genus *Pythium* (Pringsheim, 1858) since the latter likewise was erected on a nematoid or filamentous species. In view of the existence of forms having sporangia consisting in part of subspherical and part filamentous elements, the extension of the genus *Pythium* to include species with wholly subspherical sporangia appears in conformity with sound taxonomic usage (see Drechsler, Wash. Acad. Sci. 20:398-9. 1930). See *Pythium arrhenomanes* Drechsler.

*Nematosporangium arrhenomanes* (Drechsler) Sideris var. *hawaiiensis* Sideris  
See *Pythium arrhenomanes* Drechsler

*Nematosporangium epiphanosporon* Sideris See *Pythium arrhenomanes* Drechsler

- Nematosporangium hyphalosticton* Sideris See *Pythium arrhenomanes* Drechsler  
*Nematosporangium leiohyphon* Sideris See *Pythium arrhenomanes* Drechsler  
*Nematosporangium leucosticon* Sideris See *Pythium arrhenomanes* Drechsler  
*Nematosporangium polyandron* Sideris See *Pythium arrhenomanes* Drechsler  
*Nematosporangium rhizophthoron* Sideris See *Pythium arrhenomanes* Drechsler  
*Nematosporangium spaniogamon* Sideris See *Pythium arrhenomanes* Drechsler  
*Nematosporangium thysanohyphalon* Sideris See *Pythium arrhenomanes* Drechsler

NEUROSPORA CRASSA Shear and Dodge, Jour. Agric. Res. 34:1026, illus. 1927.  
 Stat. conid.=*Monilia crassa* Shear and Dodge, l. c.

*Hypocreaceae*. Pulvinate, then effuse and forming fluffy aerial masses, pale salmon to light orange; conidia catenulate, connected by narrow isthmi, globose to subglobose, smooth, yellow to pale orange in mass, 6-8  $\mu$  diam.; perithecia superficial, smooth, or loosely soft hairy, 400-600  $\mu$  diam.; ascospores elliptical, with about 20 longitudinal ridges, dark brown to black, 23-32  $\times$  11-16  $\mu$ . On bagasse. Louisiana.

NEUROSPORA SITOPHILA Shear and Dodge, Jour. Agric. Res. 34:1026, 4 pls. 1927.  
 Stat. conid.=*Monilia sitophila* (Mont.) Sacc., *Michelia* 2:359. 1882. Sacc., Syll. Fungorum 4:35. 1886. Johnston and Stevenson, Jour. Dept. Agric. P. Rico. 1:222. 1917.

*Hypocreaceae*. Pulvinate fluffy masses, pale salmon to orange; conidia catenulate, connected by narrow isthmi, globose to subglobose, 10-12  $\mu$  diam.; perithecia superficial, smooth, brown to black, subcoriaceous, 200-300  $\mu$  diam.; ascospores elliptical, olivaceous to dark greenish-black, 16-17 ribbed, 20-26  $\times$  10-15  $\mu$ . On burnt cane in fields, on bagasse and press-cake piles, etc. Hawaii, Louisiana, Puerto Rico.

NIGROSPORA sp.

*Dematiaceae*. An undetermined species associated saprophytically with ring spot lesions. Florida.

NIGROSPORA ORYZAE (Berk. and Br.) Petch, Jour. Indian Bot. Soc. 4:21-24. 1924. Mason, Trans. Brit. Myc. Soc. 12:156. 1927. Sacc., Syll. Fungorum 25:775. 1931. *Nigrospora panici* Zimm., Centralbl. f. Bakt. Abt. II, 8:220. 1902. Sacc., Syll. Fungorum 18:571. 1906. *Basisporium gallarum* Moll., Bull. Soc. Myc. Fr. 18:170, 1 pl. 1902. Sacc., Syll. Fungorum 18:533. 1906.

*Dematiaceae*. Conidiophores inflated (ampulliform or "jar-shaped"); conidia borne singly, black, opaque, round from top view, flattened in side view, about 14  $\mu$  diam. Forming black sooty areas on dead and dying leaves, leaf-sheaths and stalks, also commonly at nodes of sound canes. Barbados, Hawaii, Java, Puerto Rico.

Bremer (Meded. Proefsta. Java Suikerind. 22:885-96. 1926) uses the binomial *N. panici* for a form isolated from spots on leaf-sheaths in Java. From the conidial size given (14-18  $\times$  11-16  $\mu$ ) it is not clear to just which of the

three species recognized by Mason (l. c.) this form should be assigned. Bremer also states that his fungus appeared to be a form of *Melanconium sacchari* Mass. His evidence is inadequate.

*Nigrospora panici* Zimm. See *Nigrospora oryzae* (Berk. and Br.) Petch

NIGROSPORA SACCHARI (Speg.) Mason, Trans. Brit. Myc. Soc. 12:161. 1927. *Glenospora sacchari* Speg., Rev. Fac. Agron. y Vet. 2:249. 1896. Sacc., Syll. Fungorum 14:1074. 1899.

*Dematiaceae*. Differs from *N. oryzae* in the larger conidia (20-22  $\mu$  in largest diameter). On dying leaves and culms. Argentina.

NIGROSPORA SPHAERICA (Sacc.) Mason, Trans. Brit. Myc. Soc. 12:158. 1927. Sacc., Syll. Fungorum 25:775-6. 1931. *Epicoccum levisporum* Pat., Bull. Soc. Myc. Fr. 9:164. 1893. Sacc., Syll. Fungorum 11:655. 1895. *Coniosporium extremorum* Syd., Ann. Myc. 11:270. 1913. Sacc., Syll. Fungorum 25:754. 1931.

*Dematiaceae*. Differs from *N. oryzae* in size of conidia only (16-18  $\mu$ ). On dead and dying leaves, leaf-sheaths, and canes. Ecuador, Gold Coast, Philippine Islands, Uganda.

NORTHIELLA SACCHARI Lyon, Exp. Sta. Hawaii. Planters' Assoc. (Bot. Ser.) Bull. 3, pt. I:41. 1921. A temporary name applied to organism-like, intracellular bodies in Fiji-disease galls, since classified as a transmissible virus disease (Mungomery and Bell, Queensland Bur. Sugar Exp. Sta's, Div. Path. Bull. 4. 1933. Ocfemia, Amer. Jour. Bot. 21:113-20. 1934. See *Phytamocha sacchari* McWhorter

#### ODONTIA

*Hydnaceae*. Undetermined species as saprophytes on cane trash and associated with root rot reported from Cuba, Puerto Rico, Trinidad.

ODONTIA SACCHARI Burt, Ann. Mo. Bot. Garden 4:233-4, fig. 1. 1917. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:217, pl. XXVI (figs. 11-12). 1917. Sacc., Syll. Fungorum 23:485. 1925.

*Hydnaceae*. Fructifications resupinate, effused, white to ivory yellow; granules about 8 per mm; cystidia incrustated, hyaline, protruding 60-90  $\mu$ ; spores hyaline, smooth, subglobose,  $3.75 \times 3-3.75 \mu$ . On dead leaf-sheaths. Cuba, Puerto Rico, Trinidad. Cuban specimens referred to *Peniophora* sp. and *Hypochnus sacchari* Speg. belong here per Dr. Burt.

ODONTIA SACCHARICOLA Burt, Ann. Mo. Bot. Garden 4:235-6, fig. 2. 1917. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:189, pl. XIX (fig. 1). 1917. Sacc., Syll. Fungorum 23:486. 1925.

*Hydnaceae*. Fructifications resupinate, effused, very thin, whitish; granules 6-9 per mm; cystidia hair-like, flexuous, not incrustated, 8-18  $\mu$  long; stellate crystals interhyphal, 4.5-5.7  $\mu$  diam.; spores hyaline, smooth,  $5.5 \times 2.5 \mu$ . Rotting and binding firmly together lower leaf-sheaths. *Himantia stellifera* is possibly a sterile form of this species. British Guiana, Cuba, Dominican Republic, Hawaii, Lesser Antilles, Puerto Rico, Trinidad, Union So. Africa.

## OEDOCEPHALUM sp.

*Moniliaceae*. An undetermined species associated saprophytically with diseased roots. Louisiana.

OEDOCEPHALUM BERGII Speg., Rev. Fac. Agron. y Vet. 2:244. 1896. Sacc., Syll. Fungorum 14:1042. 1899.

*Moniliaceae*. Conidia hyaline,  $10-20 \times 6-10 \mu$ . A white mold on dead leaves and culms. Argentina.

OLPIDIUM SACCHARI Cook, Jour. Agric. Univ. P. Rico 19:127, 6 pls. 1935.

*Chytridiaceae*. Sporangia usually solitary in cells of host, multinucleate, germinating by single tube; zoospores numerous, uninucleate, amoeboid; resting spores spherical and thick-walled. In diseased roots. Puerto Rico.

## OOSPORA sp.

*Moniliaceae*. An undetermined saprophytic species associated with root rot. Louisiana.

OOSPORA TOMENTELLA Speg., Rev. Fac. Agron. y Vet. 2:243. 1896. Sacc., Syll. Fungorum 14:1039. 1899.

*Moniliaceae*. Conidia hyaline, catenulate, globose or ellipsoid,  $1.9-2 \mu$ . On rotting cane spindles. Argentina.

*Ophiobolus stenospilus* Carpenter See *Cochliobolus stenospilus* (Carpenter) Matsumoto and Yamamoto

OPHIOGNOMONIA SACCHARI Speg., Rev. Fac. Agron. y Vet. 2:231. 1896. Sacc., Syll. Fungorum 14:613-14. 1899.

*Sphaeriaceae*. Perithecia amphigenous, globose,  $150 \mu$  diam.; spores hyaline, 1-celled, cylindrical,  $70-80 \times 5 \mu$ . On dying lower leaves. Argentina. This genus is usually considered synonymous with *Linospora*.

## OTTHIA sp.

*Sphaeriaceae*. Avena Sacca (Bol. Agric. São Paulo 17:626-8, 1 fig. 1916) reports an undetermined species on dead canes. Brazil.

OZONIUM SACCHARI Speg., Rev. Fac. Agron. y Vet. 2:257. 1896. Sacc., Syll. Fungorum 14:1188. 1899.

*Mycelia sterilia*. Sterile mycelium on dead leaf-sheaths. Argentina.

PAECILOMYCES VARIOTI Bainier, Bull. Soc. Myc. Fr. 23:26, pl. VII. 1907. Sacc., Syll. Fungorum 22:1273. 1913. Thom, The Penicillii, p. 544. 1930. *Penicillium divaricatum* Thom, U. S. Dept. Agric. Bur. Animal Ind. Bull. 118:72-73, fig. 29. 1910.

*Moniliaceae*. Cultures yellowish-brown; fructifications terminal or on short branches from creeping hyphae; conidia long catenulate, elliptical or fusiform, yellowish to brownish,  $5-7 \times 2.5-3 \mu$ . On sugar. Union So. Africa. The genus considered a synonym of *Penicillium* by Clements and Shear, Genera of Fungi, p. 388. 1931.

*Papularia arundinis* (Cda.) Fr. See *Coniosporium arundinis* (Cda.) Sacc.

*Papularia saccharina* (Penz. and Sacc.) v. Hoeh. See *Papularia vinosa* (Berk. and Curt.) Mason

PAPULARIA VINOSA (Berk. and Curt.) Mason, Annotated Account of Fungi Received at the Imp. Myc. Inst. List II (Fasc. 2), p. 21. 1933. *Gymnosporium vinosum* Berk. and Curt., Jour. Linn. Soc. Bot. 10:355. 1869. *Coniosporium vinosum* (Berk. and Curt.) Sacc., Syll. Fungorum 4:244. 1886. *Melanconium saccharinum* Penz. and Sacc., Malpighia 15:238. 1901. Penz. and Sacc., Icones Fung. Javan. 97, pl. LXV (fig. 3). 1904. Sacc., Syll. Fungorum 18:471. 1906. *Papularia saccharina* (Penz. and Sacc.) v. Hoeh., Fragm. z. Mykol. No. 1184. 1919. *Melanconium lincolatum* Sacc., Atti. Ven.-Trent. Sci. Nat. 10:83. 1917. Sacc., Syll. Fungorum 25:582. 1917.

*Melanconiaceae*. Sporodochia linear, erumpent, black; conidia black, smooth, lenticular, often distorted, 18-26  $\mu$  diam., up to 14  $\mu$  in breadth, on phialide-like sporophores, occasionally loosely aggregated in heads. On dead and dying leaves and culms, particularly along midribs. Ceylon, Cuba, Louisiana, Philippine Islands, Puerto Rico, Uganda.

PENICILLIUM spp. (including *Citromyces*).

*Moniliaceae*. Undetermined species associated with root rot or foot rot, on cane trash, and as agents of sugar deterioration. Hawaii, Java, Louisiana, and doubtless all other cane regions. Thom (The Penicillii, p. 133. 1930) notes "studies tend to eliminate the Penicillia from any significant role in sugar deterioration."

*Penicillium divaricatum* Thom See *Paecilomyces varioti* Bainier

PENICILLIUM EXPANSUM (Link) emend. Thom, U. S. Dept. Agric. Bur. Animal Ind. Bull. 118:27-28, 1 fig. 1910. Thom, The Penicillii, p. 402, 1 fig. 1930.

*Moniliaceae*. Colonies green to gray-green, finally brown; conidiophores grouped to form coremia; conidia elliptical to globose, green, catenulate, 3-3.4  $\mu$ . On sugar. Louisiana.

PENICILLIUM GLAUCUM Link, Obs. Myc. 1:15. 1809. Sacc., Syll. Fungorum 4:78. 1886.

*Moniliaceae*. Reported as an agent of sugar deterioration and on dead cane (?). Hawaii, Java, Louisiana. Thom (The Penicillii, pp. 560-1. 1930) states that the species was originally inadequately described, has been used as a dumping ground for a variety of forms, and being now undeterminable should be deleted.

PENICILLIUM LUTEUM Zukal, Sitzber. K. Akad. Wiss. (Vienna) Math. Naturw. Kl. 98:521. 1888. Sacc., Syll. Fungorum 11:593. 1895. Thom, The Penicillii, p. 448. 1930.

*Moniliaceae*. Conidia ellipsoid, gray-green, smooth,  $2.3 \times 1.4 \mu$ ; ascospores, transversely tricostate,  $4.8 \times 3.3 \mu$ . On spoiling sugar. Java, Louisiana.

PENICILLIUM PFEFFERIANUM (Wehmer) Pollacci, Atti. Inst. Bot. Univ. Pavia Ser. II, 16:121-36, pl. XVI. 1916. Thom, The Penicillii, p. 186. 1930. *Citromyces pfefferianus* Wehmer, Beitr. z. Kenntn. einheim. Pilze 1:22-24, pl. I (figs. 1-13). 1893. Sacc., Syll. Fungorum 14:1048. 1899.

*Moniliaceae*. Colonies greenish to gray; conidiophores simple or branched, scarcely or rarely septate,  $70 \times 3 \mu$ ; conidia globose, long catenulate, green to gray, 2.5-3  $\mu$ . In sugar solutions. Germany.

**PENICILLIUM PLATENSE** Speg., Rev. Fac. Agron. y Vet. 2:246-7. 1896. Sacc., Syll. Fungorum 14:1047-48. 1899. Thom, The Penicillii, p. 196. 1930.

*Moniliaceae*. Colonies glaucous green; conidia long, catenulate, smooth, pale green,  $2-2.5\ \mu$  diam. On rotten leaves. Argentina.

**PENICILLIUM PURPUROGENUM** Stoll, Beitr. zu Morph. u. Biol. Char. Penicillium, p. 32, pls. I (fig. 6), III (fig. 2). 1904. Sacc., Syll. Fungorum 18:520. 1906. Thom, U. S. Dept. Agric. Bur. Animal Ind. Bull. 118:36, fig. 5. 1910. Thom, The Penicillii, p. 478. 1930.

*Moniliaceae*. Colonies green, conidiophores  $100-300 \times 3-3.5\ \mu$ ; conidia  $3.4-3.8 \times 2-2.5\ \mu$ . On sugar. Louisiana.

*Penicillium roseum* Link See *Gliocladium roseum* (Link) Bainier

**PENICILLIUM RUBRUM** Stoll, Beitr. z. Morph. u. Biol. Char. Penicillium, p. 35, pls. I (fig. 7), III (fig. 3). 1904. Sacc., Syll. Fungorum 18:520. 1906. Thom, The Penicillii, p. 476. 1930.

*Moniliaceae*. Conidia elliptical, yellow to dark green,  $3.4 \times 2\ \mu$ . On spoiling sugar. Java.

**PENICILLIUM SACCHARI** J. Ray, Rev. Gen. Bot. 9:294-300, pl. 16 (figs. 23-27). 1897. Sacc., Syll. Fungorum 22:1276. 1913. Thom, The Penicillii, p. 452. 1930.

*Moniliaceae*. Mycelial masses yellow to orange; conidia green,  $2 \times 1\ \mu$ ; asci 6-spored, imbedded in the mycelium; ascospores thick walled,  $3 \times 2.5\ \mu$ . On rotten culms. Martinique.

**PENIOPHORA** spp.

*Thelephoraceae*. Undetermined species on dead canes. Puerto Rico. Cuban report=*Odontia sacchari* (q. v.).

**PENIOPHORA CINEREA** (Pers.) Cke., Grevillea 8:20, pl. 123 (fig. 8). 1880. Sacc., Syll. Fungorum 6:643. 1888. Burt, Ann. Mo. Bot. Garden 12:348. 1925.

*Thelephoraceae*. Effused, thin, closely adnate, ashen colored, cracking in drying; cystidia incrusted,  $25-40 \times 4.5-9\ \mu$ ; spores smooth, cylindrical,  $6-9 \times 2-3\ \mu$ . On dead canes. Puerto Rico.

**PENIOPHORA FLAVIDO-ALBA** Cke., Grevillea 8:21, pl. 125 (fig. 14). 1879. Sacc., Syll. Fungorum 6:644. 1888. Burt, Ann. Mo. Bot. Garden 12:248. 1925.

*Thelephoraceae*. Fructifications broadly effused, 5-15 cm long, thin, cart-ridge buff to pinkish buff; cystidia incrusted, sharp pointed, 60-120  $\mu$  long; spores hyaline, smooth,  $4.5-6 \times 2.5-3.5\ \mu$ . On cane trash. Puerto Rico.

**PERICONIA ATRA** Cda., Icones Fung. 1:19, fig. 258. 1837. Sacc., Syll. Fungorum 4:271. 1886.

*Dematiaceae*. Conidia globose, brown. On dead cane leaves. St. Croix.

**PERICONIA SACCHARI** Johnston, Jour. Dept. Agric. P. Rico 1:225, pl. XXIX (figs. 16-18). 1917. Sacc., Syll. Fungorum 25:769. 1931.

*Dematiaceae*. Fertile hyphae erect, brown, short branched, 200-300  $\mu$ ; conidia ovoid or elliptical, cylindrical when mature, brown, tuberculate,  $22-24 \times 11\ \mu$ . On dead and dying cane leaves. Cuba, Puerto Rico.



*PESTALOTZIA FUSCESCENS* Sor. var. *SACCHARI* Wakker in Wakker and Went, Ziekten Suikerriet op Java, pp. 162-6, col. pl. XVIII (figs. 1-8). 1898.

*Melanconiaceae*. Conidia 5-celled, with 4-setae,  $32-38 \times 14-16 \mu$ . Irregular ashen leaf spots with brown borders. On living leaves. Cuba, India, Java, Mauritius, Philippine Islands, Queensland.

*PHAEONECTRIA SACCHARI* da Camara, Anais do Inst. Sup. de Agron. 3:80, figs. 20-23. 1930. (Preprint, p. 30. 1929.)

*Hypocreaceae*. Perithecia solitary or gregarious, subglobose,  $260-340 \mu$  diam.; spores oblong-ellipsoid, 1-septate, constricted at septum, upper cell longer and more attenuate, lower globose, brown,  $15-18 \times 4.5-5 \mu$ . On dead culms. Portugal.

*Phaeoporus luteocumbrinus* Rom. See *Polyporus luteo-umbrinus* (Rom.) Sacc.

*Phallus celebicus* P. Henn. See *Ithyphallus rubicundus* (Bosc) Fischer

*Phallus multicolor* (Berk. and Br.) Lloyd See *Dictyophora multicolor* Berk. and Br.

*Phallus rubicundus* (Bosc) Fr. See *Ithyphallus rubicundus* (Bosc) Fischer

*PHOMA* sp.

*Phomaceae*. An unnamed saprophytic species associated with root rot. Louisiana.

*PHOMA BAMBUSINA* Speg. in Bailey, Bot. Bull. Queensland Dept. Agric. 1894, p. 37, 1894 and Report Queensland Dept. Agric. 1894-5, p. 36. 1895.

*Phomaceae*. On stalks of seedlings. Queensland. No further details found. It is noted that McAlpine (Systematic Arrangement Austr. Fungi, p. 170. 1895) soon after Bailey's report was made lists *Phomia sacchari* (q. v.) but not *Ph. bambusina*.

*PHOMA HETEROSPORA* Speg., Rev. Fac. Agron. y Vet. 2:239. 1896. Sacc., Syll. Fungorum 14:887. 1899.

*Phomaceae*. Pycnidia in pale, wide-spreading spots; conidia dimorphic, one elliptical-subglobose,  $10-12 \times 6-8 \mu$ ; the second fusoid, much smaller. On leaves and spindles killed by freezing. Argentina. Spegazzini suggests that this is a pycnidial stage of *Sphaerella sacchari*.

*PHOMA INSIDIOSA* Tassi, Bull. Lab. Bot. della R. Univ. Siena 1:8, pl. IX (fig. 8). 1897. Sacc., Syll. Fungorum 14:887-8. 1899.

*Phomaceae*. On cane leaves through inoculation. Kock and Rumbold, Phytopath. 11:259. 1921.

*Phoma sacchari* (Cke.) Sacc. See *Macrophoma sacchari* (Cke.) Berl. and Vogl.

*PHOMA SACCHARI* Gutner, Acta Insti. Bot. Acad. Scientiarum U. S. S. R., Ser. II (Fasc. III), p. 789. 1936.

*Phomaceae*. Pycnidia numerous, semiglobose,  $200-230 \mu$  diam.; conidiophores bacillar; conidia cylindrical or elongate ellipsoid, both ends obtuse,  $4-8 \times 2.8 \mu$ . On dying leaves in greenhouses. U. S. S. R.

*PHOMA SACCHARINA* Syd., Ann. Myc. 14:187. 1916. Sacc., Syll. Fungorum 25:95. 1931.

*Phomaceae*. Pycnidia lenticular to elliptical, dark brown,  $50-80 \mu$  diam.; conidia globose to ovate-globose, 1-celled, hyaline,  $2.5-3.5 \mu$ . On culms. India.

*Phyllachora cyperi* Rehm var. *donacis* Berl. and F. Sacc. See *Phyllachora sacchari-spontanei* Syd.

PHYLLACHORA SACCHARI P. Henn., Hedw. 41:143. 1902. Sacc., Syll. Fungorum 17:839-40. 1905. Theissen and Sydow, Ann. Myc. 13:459. 1915.

*Dothidiaceae*. Stromata epiphyllous, black, 1-1.5 mm long, paraphysate; spores elliptical, obtuse at ends, hyaline,  $16-20 \times 9-10 \mu$ . On living leaves.

*Black leaf-spot.*

Argentina, India, Java, Philippine Islands. The report of this species on *S. spontaneum* in India should possibly be referred to *Ph. sacchari-spontanei*.

PHYLLACHORA SACCHARI-AEGYPTIACI Br. and Cav., I Fungi Parassiti delle Pianta Colt. od Utili, n. 416. 1909. Sacc., Syll. Fungorum 22:423. 1913.

*Dothidiaceae*. Stromata oblong, arranged in rows, confluent; paraphyses filiform; spores ellipsoid or ovoid, yellowish, smooth,  $19-20 \times 7.5-9.5 \mu$ . On leaves of *Saccharum aegyptiacum* (*S. spontaneum*). Sicily.

PHYLLACHORA SACCHARI-SPONTANEI Syd., Phil. Jour. Sci. 8:279. 1913. Theissen and Sydow, Ann. Myc. 13:459. 1915. Sacc., Syll. Fungorum 24:586. 1926.

*Dothidiaceae*. Stromata on yellow or reddish-violet spots, .5-1.75 mm long, paraphysate; spores 1-celled, hyaline,  $22-25 \times 7.5-8.5 \mu$ ; conidia filiform, hyaline, straight or curved,  $16-22 \times 1 \mu$ . On living leaves of *Saccharum spontaneum*. China, India, Philippine Islands. A specimen from India referred to *Ph. cyperi donacis* Berl. and F. Sacc. (Ann. Myc. 9:399. 1911) was afterwards transferred to *Ph. sacchari-spontanei*.

PHYLLOSTICTA sp.

*Phomaceae*. An undetermined species on leaves. Brazil.

PHYLLOSTICTA HAWAIIENSIS Caum, Hawaii. Planters' Rec. 20:278. 1919. Caum, Exp. Sta. Hawaii. Sugar Plant. Assoc. (Bot. Ser.) Bull. 3:81, figs. 1-4. 1921. Sacc., Syll. Fungorum 25:43. 1931.

*Phomaceae*. Pycnidia erumpent, globose, 30-168  $\mu$ , on definite, dry, straw-colored spots with dark red to purple margins; conidia elliptical, hyaline, smooth, 2-3 vacuolate,  $3.2-6.5 \times 1.3-2.8 \mu$ . Parasitic at base of leaf-sheaths and on rind beneath. Hawaii. Bourne (Fla. Agr. Exp. Sta. Bull. 267:28-31, 1934) considers this species a synonym of *Phyllosticta sorghina* Sacc.

PHYLLOSTICTA SACCHARI Speg., Rev. Fac. Agron. y Vet. 2:239. 1896. Sacc., Syll. Fungorum 14:864. 1899. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:220, pl. XXIV (fig. 4). 1917.

*Phomaceae*. Pycnidia 90-100  $\mu$  diam.; in definite, ashen, linear spots, 1-25 cm long, 1-10 mm wide, amphigenous, purple bordered; conidia ellipsoid, hyaline,  $4-6 \times 2-3 \mu$ . On living leaves. Argentina, Brazil, Paraguay, Philippine Islands, Puerto Rico. The Puerto Rican fungus is reported with conidia  $12-16 \times 2.5-4 \mu$ , suggesting that it is distinct from Spegazzini's species. Bourne (l. c.) considers *P. sacchari* Speg. a synonym of *Phyllosticta sorghina* Sacc.

PHYLLOSTICTA SACCHARICOLA P. Henn., Flora du Bas et Moyen Congo 2:105. 1907. Sacc., Syll. Fungorum 22:863. 1913.

*Phomaceae*. Spots amphigenous, oblong, ashen with fuscous or reddish margins; pycnidia hypophyllous, 60-90  $\mu$  diam.; conidia oblong to subfusoid, hyaline, 10-30  $\times$  3.3-5  $\mu$ . On living leaves. Belgian Congo. Bourne (l. c.) considers this species a pycnidial stage of *Leptosphaeria sacchari*.

PHYLLOSTICTA SORGHINA Sacc., Mich. Comm. Mycol. 1:140. 1879. Sacc., Syll. Fungorum 3:61. 1884. Possible synonyms *P. hawaiiensis* Caum and *P. sacchari* Speg. Bourne, Fla. Agric. Exp. Sta. Bull. 267, illus. 1934.

*Phomaceae*. Pycnidia 44-147  $\mu$  in diam.; conidia 3.4-6.7  $\times$  1.7-3.4  $\mu$ . Saprophytic on leaf, leaf-sheath, and stem as a secondary invader to *Helminthosporium ocellum* Faris and "changing eye spot lesions to ring spots" (Bourne). Florida, Puerto Rico.

PHYSALOSPORA EUCRYPTA Petrak, Ann. Myc. 21:312-13. 1923.

*Sphaeriaceae*. Perithecia immersed, paraphysate; spores long ellipsoid, hyaline, 1-celled, 11-14  $\times$  4.5-6  $\mu$ . On dead leaves. Philippine Islands.

PHYSALOSPORA PARAGUAYA Speg., Anal. Soc. Cient. Argentina 18:266. 1884. Sacc., Syll. Fungorum 9:598. 1891. (As *P. paraguaxa*.)

*Sphaeriaceae*. Perithecia erumpent, globose, black, glabrous, 150-180  $\mu$  diam., paraphysate; spores elliptical, rounded at the ends, hyaline, 5-8  $\times$  2.5  $\mu$ . On rotten canes. Brazil.

PHYSALOSPORA RHODINA (Berk. and Curt.) Cke., Grevillea 17:92. 1889. Sacc., Syll. Fungorum 9:592. 1891. Stevens, Mycologia 18:212. 1926. *Botryodiplodia theobromae* Pat., Bull. Soc. Myc. Fr. 8:136. 1892. Sacc., Syll. Fungorum 11:522. 1895. Butler, Fungi and Disease in Plants, pp. 385-7. 1918. *Diplodia cacaoicola* P. Henn., Engl. Bot. Jahrb. 22:80. 1895. Sacc., Syll. Fungorum 14:931. 1899. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:220-1, pls. XXI (fig. 1), XXXI (figs. 8-10). 1917. *Lasiodiplodia theobromae* (Pat.) Griff. and Maubl., Bull. Soc. Myc. Fr. 25:57. 1909. Sacc., Syll. Fungorum 22:1011. 1913. *Thyridaria tarda* Bancroft, Dept. Agric. Fed. Malay States Bull. 9:26. 1911. Sacc., Syll. Fungorum 24:770. 1928.

*Sphaeriaceae*. Pycnidia scattered, innate-erumpent, black; conidia ellipsoid, oblong, or subovoid, 1-septate, obtuse at both ends, deep brown to black, faintly striate, 18-22  $\times$  10-14  $\mu$ ; perithecia gregarious, black, 250-300  $\mu$  diam.; spores hyaline, 24-42  $\times$  7-17  $\mu$ . Dry rot.

Alabama, Barbados, Brazil, British Guiana, British W. Indies, Cameroons, Ceylon, Cuba, Dominican Republic, India, Indo-China, Java, Malay States, Philippine Islands, Puerto Rico, Samoa, St. Thomé, Trinidad, "Tropical American in general." Bancroft (l. c.) described *Thyridaria tarda* as the perfect stage of the cane *Diplodia*, but carried out no cultural work to prove a connection. He also mentions an associated *Cytospora* stage.

PHYSALOSPORA SACCHARI (Berk. and Br.) Sacc., Syll. Fungorum 9:599. 1891.

*Sphaeriaceae*. Spores oblong, 1-celled, hyaline, 3-7  $\mu$  long. On leaves. Queensland.

PHYSALOSPORA TUCUMANENSIS Speg., Rev. Fac. Agron. y Vet. 2:228. 1896. Sacc., Syll. Fungorum 14:523. 1899.

*Sphaeriaceae*. Perithecia 110-130  $\mu$  diam., in rows between leaf veins, erumpent; spores 1-celled, hyaline, smooth, obtuse at both ends,  $18-22 \times 8-10 \mu$ . On old and dying leaves. Argentina, Puerto Rico.

PHYSARUM CINEREUM (Batsch) Pers. in Roemer, N. Mag. Bot. 1:89. 1794. Sacc., Syll. Fungorum 7:344. 1888. Macbride and Martin, The Myxomycetes, pp. 45-46, pl. III (figs. 45, 46). 1934.

*Physaraceae*. Sporangia sessile, subglobose to elongate, lilaceous gray; spore mass purplish-brown; spores warted, 7-11  $\mu$  diam. On cane trash, at times fruiting on living parts. Puerto Rico.

PHYSARUM COMPRESSUM Alb. and Schw., Consp. Fung., p. 97. 1805. Sacc., Syll. Fungorum 7:337. 1888. Macbride and Martin, The Myxomycetes, p. 74, pl. V (figs. 93-95). 1934.

*Physaraceae*. Sporangia compressed-globose, stipitate or sessile, white or ashen, calcareous; spores purplish-brown, warted, 10-12.5  $\mu$  diam. On cane trash. Argentina, Puerto Rico.

PHYSARUM DIDERMOIDES (Ach.) Rost. Monog., p. 97. 1875. Sacc., Syll. Fungorum 7:338. 1888. Macbride and Martin, The Myxomycetes, p. 70, pl. V (figs. 88, 89). 1934.

*Physaraceae*. Sporangia crowded, ovoid or cylindrical, stipitate or sessile, blue-gray, often capped with white, .4-.6 mm broad; spores black in mass, densely spinulose, 12-15  $\mu$  diam. Reported on cane trash by Caum. No other record found.

PHYSARUM GLOBULIFERUM (Bull.) Pers., Syn. Meth. Fung., p. 175. 1801. Sacc., Syll. Fungorum 7:339. 1888. Macbride and Martin, The Myxomycetes, pp. 63-4, pl. V (figs. 76-78). 1934.

*Physaraceae*. Sporangia stipitate, globose, about 5 mm diam., pale blue-gray to white; stipe calcareous, brittle, white to yellow; spore mass brown; spores violet, minutely warted, 7.5-9  $\mu$ . Reported on *Saccharum* by Caum, but not by Saccardo.

*Physarum nodulosum* Cke. and Balf. See *Physarum pusillum* (Berk. and Curt.) Lister

PHYSARUM PUSILLUM (Berk. and Curt.) Lister, Mycetozoa, ed. 2, p. 64. 1911. Macbride and Martin, The Myxomycetes, p. 80, pl. VI (figs. 105-6). 1934. *Physarum nodulosum* Cke. and Balf. in Rav., N. Amer. Fung. Exsic. 479. 1881. (Nomen nudum.)

*Physaraceae*. Sporangia gregarious, stipitate, globose, grayish-white, then white, with brown base, .4-.6 mm diam.; stipe slender, longer than sporangia; spores black in mass, minutely warted, 10-12  $\mu$  diam. On dead material, fruiting on living leaf-sheaths. Puerto Rico.

PHYSARUM TUCUMANENSIS Speg., Rev. Fac. Agron. y Vet. 2:237. 1896. Sacc., Syll. Fungorum 14:831. 1899.

*Physaraceae*. Sporangia globose, 300-500  $\mu$  diam.; spores smooth, globose, 9-10  $\mu$  diam. The species not recognized by Macbride and Martin; doubt-

fully referred to *Physarum melleum* Mass., Monogr., p. 278, 1892, by Lister (3rd ed., p. 25).

PHYTAMOEBA SACCHARI McWhorter, Phil. Agric. 11:110, 2 pls. 1922.

A name applied to certain intercellular parasitic amoeba occurring in cane material infected with Fiji disease. See also *Northiella sacchari* Lyon

*Phytomonas rubrilineans* Lee, Purdy, Barnum and Martin See *Bacterium rubrilineans* (Lee, Purdy, Barnum and Martin) Elliott

*Phytomonas rubrisubalbicans* Christopher and Edgerton See under *Bacterium*

*Phytomonas vascularum* (Cobb) Bergey et al. See *Bacterium vascularum* (Cobb) Migula

PLASMIDIOPHORA VASCULARUM Matz, Jour. Dept. Agric. P. Rico 4:41-46, 3 figs. 1920. Loc. cit. 6(3):28-47, 6 figs. 1922. Sacc., Syll. Fungorum 25:12. 1931 (as *P. vascularum*). *Ligniera vascularum* (Matz) Cook, Jour. Dept. Agric. P. Rico 13:19-29, 4 pls. 1929. Loc. cit. 21:85-97, 3 pls. 1937. *Amoebosporus saccharinum* Cook, Jour. Dept. Agric. P. Rico 16:416, pl. LV (figs. 9-16). 1932. *Amoebosporus vascularum* Cook, loc. cit. 16:415, pls. LIII, LIV. 1932.

*Plasmodiophoraceae*. Plasmodium yellow, granular; resting spores in tracheal tubes, granular, orange, yellow or slightly brownish, with thick hyaline walls, 14-16  $\mu$  diam.; zoospores pyriform, uniflagellate, amoeboid. The organism occurs in the vascular tissues of the lower portion of the stalks, clogging the fibers which are colored orange, yellow, or red. Affected canes dry out, wilt, and die. Barbados, Puerto Rico, Venezuela.

*Dry top rot.*

PLECTOSPIRA GEMMIFERA Drechsler, Jour. Agric. Res. 38:358, 3 pls. 1929. Rands and Dopp, U. S. Dept. Agr. Tech. Bull. 666 (in press). 1938.

*Saprolegniaceae*. Oospores, 21.9  $\mu$  average diam.; gemmae in grape-like clusters. Isolated from cane roots, but saprophytic. Louisiana.

*Pleocyta sacchari* (Mass.) Petr. and Syd. See *Melanconium sacchari* Mass.

PLEOSPORA INFECTORIA Fckl. var. SACCHARI Speg., Rev. Fac. Agron. y Vet. 2:233. 1896. Sacc., Syll. Fungorum 14:600-1. 1899.

*Sphaeriaceae*. Perithecia in rows, globose, membranaceous, 150-160  $\mu$ , nonparaphysate; spores elliptical, muriform, smooth, yellow-brown. On dead leaves. Argentina.

POLYDESMUS sp.

*Dematiaceae*. An undetermined species on dead leaves. Puerto Rico.

POLYPORUS LUTEO-UMBRINUS (Rom.) Sacc., Syll. Fungorum 16:149. 1902.

*Phaeoporus luteoumbrianus* Rom., K. Svenska Vet.-Akad. Handl. 26:27, pl. III (fig. 45). 1901.

*Polyporaceae*. Sporophores conchate, substipitate, zonate, ferruginous-umbrinous; hyphae 2-4.5  $\mu$  diam.; cystidia none; pores 6-9 per mm; spores umbrinous, globose-ellipsoid, 4.5-5  $\times$  3.5-4  $\mu$ . Weak parasite on old stools. Argentina.

*Polyporus nivosus* Berk. See *Trametes nivosus* (Berk.) Murr.

**POLYPORUS OCCIDENTALIS** Klotzsch, Linnaea 8:486. 1833. *Polystictus occidentalis* (Klotzsch) Cke., Grevillea 14:85. 1886. Sacc., Syll. Fungorum 6:274. 1888. *Corioloropsis occidentalis* (Klotzsch) Murr., Bull. Torr. Bot. Club 32:358. 1905.

*Polyporaceae*. Pileus corky, applanate, zonate, tomentose, gray-ochraceous to grayish isabelline; context 1-6 mm thick; pores 2-4 per mm, isabelline; spores allantoid, smooth, hyaline,  $5-7 \times 2-3 \mu$ . Puerto Rico.

**POLYPORUS SANGUINEUS** (L.) Meyer, Flor. Esseq., p. 304. 1818. Fries, Epicr. Myc., p. 444. 1838. *Polystictus sanguineus* (L.) Fr., Nov. Symb., p. 75. 1851. Sacc., Syll. Fungorum 6:229. 1888. *Pycnoporus sanguineus* (L.) Murr., Bull. Torr. Bot. Club 31:421. 1904.

*Polyporaceae*. Sporophores thin, coriaceous, sessile, dimidiate, bright red, glabrous; context cinnabar, 1-3 mm thick; tubes 3-5 per mm; spores smooth, hyaline, oblong,  $3-4 \times 1-2 \mu$ . On dead canes. Argentina, Puerto Rico.

**POLYPORUS TULIPIFERUS** (Schw.) Overholts, Wash. Univ. Stud. 3:29. 1915. *Polystictus sinuosus* (Fr.) Lloyd, Myc. Writ. 5:626. 1917.

*Polyporaceae*. Fruiting bodies mostly resupinate; context very thin, white; pores angular, soon splitting into teeth, about 2 per mm; spores hyaline, smooth,  $6-7 \times 2-3 \mu$ . On dead stalks. Puerto Rico.

**POLYSCYTALUM SACCHARI** Speg., Rev. Fac. Agron. y Vet. 2:243. 1896. Sacc., Syll. Fungorum 14:1040-1. 1899.

*Moniliaceae*. Mycelium effuse, superficial, arachnoid; conidia cylindrical to fusoid, hyaline, smooth,  $8-14 \times 2.5-4 \mu$ . On young dying leaves. Argentina.

**PORIA AMBIGUA** Bres., Atti R. Accad. Sci. Litt. et Arti degli Agiati. 3 (ser. III): 84. 1897. Sacc., Syll. Fungorum 14:189. 1899.

*Polyporaceae*. Fruiting bodies broadly effused; pores white, large, angular, finally dentate-lacerate; spores hyaline, obovate,  $5-8 \times 3-3.5 \mu$ . Around the base of living stalks. Florida.

*Polystictus occidentalis* (Klotzsch) Cke. See *Polyporus occidentalis* Klotzsch

*Polystictus sanguineus* (L.) Fr. See *Polyporus sanguineus* (L.) Meyer

*Polystictus sinuosus* (Fr.) Lloyd See *Polyporus tulipiferus* (Schw.) Overholts

*Pseudocommis vitis* (Viala and Sauv.) Debr., Comp. Rend. Acad. Paris 120:943-5. 1895.

*Plasmodiophoraceae*. Reported as found on Seréh-diseased canes. Java. Fitzpatrick (The Lower Fungi—Phycomycetes, p. 59, 1930) states "now known to have been founded merely on the products of cell disorganization."

*Pseudomonas vascularum* (Cobb) E. F. Smith See *Bacterium vasculorum* (Cobb) Migula

**PSILOCYBE ATOMATOIDES** Peck, N. Y. State Mus. Rpt. 29:41. 1878. Sacc., Syll. Fungorum 5:1048. 1887. Thom and Lathrop., Jour. Agr. Res. 30:625-8. 1925.

*Agaricaceae*. Plants solitary to densely caespitose; pileus 3-5 cm broad, convex, smooth, fawn color to avellaneous, margins striately rugose; gills broad, rounded, adnexed to decurrent, without cystidia, becoming purple brown; stipe 3-4 mm diam.  $\times$  5-6 cm long; spores  $9-12 \times 5.5-8 \mu$ , purple

brown, unevenly elliptical, apiculate at one end; microspores on branches of mycelium becoming coiled masses of oidia  $15-30 \times 25 \mu$ . Principal cause of yellowing and deterioration in piles of baled bagasse. Louisiana.

*PTERULA CAPILLARIS* Lév., Ann. Sci. Nat. III, 2:208. 1884. Sacc., Syll. Fungorum 6:742. 1888.

*Clavariaceae*. Fruiting bodies pale ochraceous, 3-4 cm tall. On dead canes. Honduras.

*PUCCINIA KUEHNII* (Krueger) Butler, Ann. Myc. 12:81-2, 1 fig. 1914. Butler, Fungi and Disease in Plants, pp. 380-1, 1 fig. 1918. *Uromyces kuehnii* Krueger, Ber. Versuchs-Sta. f. Zuckerrohr. West-Java 1:117-121, pl. IX (col.). 1890. Sacc., Syll. Fungorum 11:182. 1895. *Uredo kuehnii* (Krueger) Wakker and Went, Ziekten Suikerriet op Java, pp. 144-6, pl. XIX (col.). 1898. Sydow, Monogr. Ured. 4:608. 1923-4.

*Pucciniaceae*. Sori on elongated orange spots, amphigenous; urediospores oval or pyriform, orange,  $29-57 \times 18-34 \mu$ ; telia black, intermixed with uredo sori; teliospores oblong to club-shaped, rounded or flattened above, narrowed below;  $25-40 \times 10-18 \mu$ ; pedicels very short, hyaline. On leaves of *Saccharum officinarum*, *S. arundinaceum*, *S. fuscum*, *S. narenga*, *S. spontaneum*. Rust.

Ceylon, China, Fiji, Formosa, Guam, India, Indo-China, Japan, Java, New So. Wales, Philippine Islands, Queensland, Sumatra.

*PUCCINIA PURPUREA* Cooke, Grevillea 5:15. 1876. Sacc., Syll. Fungorum 7:657. 1888.

*Pucciniaceae*. Sori amphigenous on broad spots; urediospores subglobose to pyriform, verrucose, yellow-brown,  $28-40 \times 20-28 \mu$ ; paraphyses numerous; teliospores smooth, ellipsoid, apices rounded,  $35-36 \times 22-32 \mu$ ; pedicels hyaline, persistent, up to  $100 \mu$  long. On leaves. Bermuda, Philippine Islands.

*Pycnoporus sanguineus* (L.) Murr. See *Polyporus sanguineus* (L.) Meyer

*PYRENOCHAETA* sp.

*Phomaceae*. An unnamed species associated with a leaf spot of the variety E. K. 28. Spots appearing on young leaves, oval, 2-5 mm in length, often coalescing, at first white, changing to tiller buff with a narrow livid brown border line. (Bitancourt, Proc. 6th Cong. Internat. Soc. Sugar Cane Tech., Baton Rouge, 1938.) São Paulo.

*PYTHIUM* spp.

*Peronosporaceae*. Unnamed species associated with root rot, Lahaina disease, etc. Brazil, British Guiana, British West Indies, Cuba, Dominican Republic, Formosa, Hawaii, Japan, Java, Louisiana, Mauritius, North Coast South America, Philippine Islands, Puerto Rico, S. E. United States.

*PYTHIUM APHANIDERMATUM* (Edson) Fitzpatrick, Mycologia 15:166. 1923. *Rheosporangium aphanidermatum* Edson, Jour. Agric. Res. 4:279, pls. 44-48. 1915. Carpenter, Exp. Sta. Hawaii. Sugar Planters' Assoc. Bull. 3 (Bot. Ser.) :59-65, pls. 16-23. 1921.

*Peronosporaceae*. Sporangia lobulate, dactyloid; oogonia terminal, smooth, spherical  $16-27 \mu$  (aver.  $22.5 \mu$ ) in diam.; antheridia one to an oogonium, usually subterminal, with a broad lateral protrusion from the normal diameter of the stalk which projects slightly beyond; antheridial stalks often connected

at some little distance with hypha bearing oogonium; oospores smooth, spherical, thick-walled, not filling oogonium. Reported in Hawaii, "an active factor in root disease of cane" (Lahaina disease), but organism subsequently identified as *Pythium butleri* Subr. and still later as *P. graminicolum* Subr. and *P. arrhenomanes* Drechsler. Infrequently isolated from rotted roots in Louisiana (Rands, Internat. Soc. Sugarcane Tech. Proc. 3:119, 1930) and found to be "weakly parasitic" on sugarcane.

**PYTHIUM ARRHENOMANES** Drechsler, *Phytopath.* 18:873-5, 1928; 26:676-84, 3 figs. 1936. Carpenter, Hawaii. *Planters' Rec.* 38:279-338, 26 figs. 1934 (as *P. graminicolum* Subr.). Rands and Dopp, *Jour. Agr. Res.* 49:189-221, 12 figs. 1934. U. S. Dept. Agr. Tech. Bull. 666 (in press). 1938. *Nematosporangium arrhenomanes* (Drechsler) Sideris, *Mycol.* 23:252-95. 1931. *N. arrhenomanes* (Drech.) Sideris, var. *hawaiiensis* Sideris (l.c.), *N. epiphano-  
sporon* Sideris (l.c.), *N. hyphalosticton* Sideris (l.c.), *N. leiophyphon* Sideris (l.c.), *N. leucosticon* Sideris (l.c.), *N. polyandron* Sideris (l.c.), *N. rhizoph-  
thoron* Sideris (l.c.), *N. spaniogamon* Sideris (l.c.), *N. thysanohyphalon* Sideris (l.c.).

*Peronosporaceae.* Sporangia lobulate, composed of inflated communicating elements up to 20  $\mu$  diam., often in extensive compound complexes; zoospores 12  $\mu$  diam. (average); oogonia (on carrot-cornmeal agar) subspherical, terminal or rarely intercalary, 21-42  $\mu$  (average 28.5  $\mu$ ) in diam.; antheridia crook-necked, numerous (4-20), at ends of branches of hyphae mostly very remotely connected with hypha bearing oogonium, rather quickly becoming indiscernible; oospores thin-walled completely filling oogonia, 20-40  $\mu$  (average 27.3  $\mu$ ). Highly variable species existing as many difficultly separable morphologic and physiologic races (Rands and Dopp, l. c.). Aggressively parasitic, causing a soft, watery, rot of root tips and rootlets of sugarcane, sorghum, maize, and other cereals and grasses. Hawaii, Mauritius, United States. *Root rot.*

**PYTHIUM ARRHENOMANES** Drechsler var. **CANADENSIS** Vanterpool and Truscott, *Canad. Jour. Res.* 6:76, pl. 1, figs. 2-3. 1932. Rands and Dopp, *Jour. Agr. Res.* 49:189-221. 1934.

*Peronosporaceae.* Stated to be different from the species in more ready production of sexual bodies and less ready formation of sporangia in culture, slightly larger oogonia, and presence of only 3-6 antheridia per oogonium. Comparison of type culture with many strains of the species by Rands and Dopp (l.c.) indicated such differences are of no practical taxonomic significance. Aggressively parasitized sugarcane roots in experiments. Canada.

*Browning root rot of cereals.*

**PYTHIUM ARRHENOMANES** Drechsler var. **PHILIPPINENSIS** Roldan, *Phil. Agric.* 19:32, 1930; 21:165-176, 4 figs. 1932.

*Peronosporaceae.* Differs from the species in fewer visible antheridia and other minor characters of dubious significance in relation to the variability of the species. Pathogenic on sugarcane roots. Causing root rot of corn. Philippine Islands.

**PYTHIUM ARTOTROGUS** (Mont.) de By., *Abh. Seneck. Ges.* 12: pl. I, and *Botan. Zeit.* 39:578. 1881. Sacc., *Syll. Fungorum* 11:244. 1895. Matthews, *Studies on the Genus Pythium*, pp. 107-10, 2 figs. 1931.



*Peronosporaceae*. Oogonia spherical, usually intercalary, 18-27  $\mu$  in diam., with few to many spiny processes, 3-6  $\mu$  long; oospores smooth, 15-24  $\mu$  in diam. In deteriorated seed cane. Louisiana.

PYTHIUM ARTOTROGUS (Mont.) deBy. var. MACRACANTHUM Sideris, Mycol. 24:47, figs. 4(c), 6(g). 1932.

*Peronosporaceae*. Differs from the species in having some epigynous antheridia, in the greater length of the spines of its oogonium, and the greater amount of aerial mycelium produced on culture media. Pathogenic on roots. Hawaii.

PYTHIUM BUTLERI Subramaniam, Mem. Dept. Agric. India (Bot. Ser.) 10:193, pls. V, VI. 1919. Drechsler, Phytopath. 24:7. 1934. Rands and Dopp, U. S. Dept. Agric. Tech. Bull. 666 (in press). 1938.

*Peronosporaceae*. Sporangia torulose to digitate, often in intricate complexes; oogonia spherical or subspherical, 18-33  $\mu$  (aver. 26  $\mu$ ) diam.; antheridia knob-shaped, terminal or intercalary, arising often from a different hypha from that bearing the oogonium; oospores spherical, smooth, thick-walled, 13.5-25.3  $\mu$  (aver. 21  $\mu$ ) in diam. Occasionally isolated from rotted rootlets. Florida.

PYTHIUM COMPLECTENS Braun, Jour. Agric. Res. 29:399, pls. 1-5. 1924. Rands and Dopp, U. S. Dept. Agric. Tech. Bull. 666 (in press). 1938.

*Peronosporaceae*. Sporangia smooth, spherical, terminal or intercalary 16.4-27.3  $\mu$  (aver. 21.8  $\mu$ ) in diam., without papilla; oogonia smooth, subspherical, 13.2-23.3  $\mu$  (aver. 18.6  $\mu$ ) in diam.; antheridia arising from same or adjacent hyphae, trumpet-shaped to broadly irregularly lobed, clasping a large part of the oogonia, persistent; oospores smooth, spherical, 11.3-20.8  $\mu$  (aver. 16.2  $\mu$ ) in diam. Infrequently isolated from weakened seed roots and not recovered in inoculation test. Louisiana. Drechsler (Phytopath. 28:84, 1938) cites this species as synonymous with *P. vexans* deBy.

PYTHIUM COMPLENS Fischer, Rab. Krypto. Flora I, Abt. 4:398, fig. 64b-f. 1892. Sacc., Syll. Fungorum 11:244. 1895. *P. gracile* deBy., Abh. Senckenb. Ges. 12, pl. 2 (figs. 6-15). 1881. Ward, Quart. Jour. Micro. Sci. 23:503-15, pls. XXXV (figs. 22-30), XXXVI (figs. 31-36). 1883.

*Peronosporaceae*. Sporangia consisting of filamentous or torulose hyphae, or enlarged, lobulate, branched complexes; oogonia intercalary, smooth, spherical, 11-25  $\mu$  (aver. 17  $\mu$ ) in diam.; antheridia 1-2, arising as short, delicate branches from the oogonial hyphae near to oogonia and forming a crook-necked structure with narrow attachment to latter. Abundantly isolated from weakened roots, but only mildly parasitic on sugarcane (Rands and Dopp, l. c.). Louisiana.

*Pythium dactyliferum* Drechsler See *P. irregulare* Buisman

PYTHIUM DEBARYANUM Hesse, *P. debaryanum*, ein endophytisches Schmarotzen, u. s. w., Inaug. Diss. Halle, p. 34, 2 pl. 1874. Sacc., Syll. Fungorum 7:271. 1888. Carpenter, Hawaii Agr. Exp. Sta. Press Bull. 54, 9 pp., 8 pls. 1919. Drechsler, Phytopath. 17:54. 1927. Rands and Dopp, U. S. Dept. Agr. Tech. Bull. 666 (in press). 1938.

*Peronosporaceae*. Oogonia smooth or sparsely papillate, spherical or subspherical, intercalary or terminal, 11-22  $\mu$  (aver. 17  $\mu$ ) in diam.; antheridia 1-2, as slightly swollen ends of longish, curved or arched antheridial branches

arising (when monoclinal) from the hyphae bearing the oogonia at a considerable distance from the latter; oospores smooth, 10-18  $\mu$  in diam. with wall 1  $\mu$  thick; zoospores moderately abundant. Associated with root rot (Lahaina disease), Hawaii; abundantly isolated and weakly parasitic on "seed" roots, and others under unfavorable conditions. Georgia, Hawaii and Louisiana.

**PYTHIUM DIAMESON** Sideris, Mycol. 24:47-8, figs. 1(D), 6(A), 7. 1932.

*Peronosporaceae*. Oogonia lateral, occasionally intercalary, spherical to subspherical, 15-17  $\mu$  in diam.; antheridia 1-2, clavate; oospores spherical, 15  $\mu$  in diam. with wall 1.5-2  $\mu$  in thickness. Pathogenic to cane roots. Hawaii.

**PYTHIUM DISSOTOCUM** Drechsler, Jour. Wash. Acad. Sci. 20:402-3. 1930. Rands and Dopp, U. S. Dept. Agric. Tech. Bull. 666 (in press). 1938.

*Peronosporaceae*. Sporangia usually undifferentiated mycelial filaments; oogonia terminal or intercalary, smooth, subspherical, 17-28  $\mu$  (aver. 22  $\mu$ ) in diam.; antheridia 1-3, crooknecked, making broad contact with oogonia, arising close to latter or from a neighboring filament; oospores smooth largely filling oogonia. Abundantly isolated from flaccid root tips and causing important damage under unfavorable conditions. Louisiana.

*Pythium gracile* deBy. See *P. complens* Fischer

**PYTHIUM GRAMINICOLUM** Subramaniam, Agric. Res. Inst. Pusa Bull. 177:5, fig. 1. 1928. Carpenter, Hawaii. Planters' Rec. 38:279-338, 26 figs. 1934. Drechsler, Phytopath. 26:676-84, 3 figs. 1936. Rands and Dopp, U. S. Dept. Agric. Tech. Bull. 666 (in press). 1938.

*Peronosporaceae*. Sporangia lobulate often forming extensive complexes somewhat like *P. arrhenomanes*; oogonia spherical, terminal, sometimes intercalary, 16.5-28.6  $\mu$  in diam.; antheridia 2-5 (visible), crooknecked, club-shaped, on hyphal branches fairly closely connected with hyphae bearing oogonia; oospores thick walled, spherical, smooth, filling oogonia, 15.4-26.4  $\mu$  in diam. Causing root rot and seedling collapse, India, and a root rot in Hawaii (?), Puerto Rico, and Louisiana.

**PYTHIUM HELICOIDES** Drechsler, Wash. Acad. Sci. 20:413-4. 1930. Rands and Dopp, U. S. Dept. Agric. Tech. Bull. 666 (in press). 1938.

*Peronosporaceae*. Aerial mycelium abundant; sporangia mostly terminal on racemose or cymoid branches, 17-45  $\times$  9-40  $\mu$  with apical papillae, often proliferous; oogonia terminal, subspherical, 26-40  $\mu$  (aver. 33  $\mu$ ) in diam.; antheridia 1-4, applied to oogonia throughout their length, terminal on branches not closely connected with oogonial hyphae, at least one of them winding about the female hyphal element in 2-4 close helical turns; oospores 21-32  $\mu$  (aver. 27.5  $\mu$ ) in diam. with wall 2.5-3.2  $\mu$  in thickness. Occasionally isolated from rootlet rot. Florida.

**PYTHIUM IRREGULARE** Buisman, Meded. Phytopath. Lab. "Willie Commelin Scholten" 11:1, figs. 9-11. 1927. Rands and Dopp, U. S. Dept. Agric. Tech. Bull. 666 (in press). 1938. *P. dactyliferum* Drechsler (nomen nudum) Rands. Cong. Internat. Soc. Sugarcane Tech. Proc. 3:122. 1930.

*Peronosporaceae*. Similar to *P. debaryanum* Hesse except for irregularities or protuberances, often 2-7 in number on oogonial wall. Occasionally isolated from weakened seed-piece roots. Louisiana.

**PYTHIUM MAMILLATUM** Meurs, Wortelrot, veroorzaakt door Schimmels, etc. Dissert. Baarn, figs. 1-3. 1928.

*Peronosporaceae*. Oogonia usually intercalary, globose with about 20 obtuse, often curved, digitate protuberances  $2.7-6\ \mu$  long; oogonia  $11-16\ \mu$  (aver.  $15\ \mu$ ) in diam. exclusive of protuberances; antheridia similar to *P. debaryanum*, but often slightly shorter and larger. Cultures provisionally identified as *P. spinosum* Sawada (see Rands, Congress Internat. Soc. Sugarcane Tech. Proc. 3:122, 1930) subsequently assigned to *P. mamillatum*. Frequently isolated from winter root-rot and pathogenic to seed-piece roots. Louisiana.

**PYTHIUM PERIILUM** Drechsler, Jour. Wash. Acad. Sci. 20:403-4. 1930. Rands and Dopp, U. S. Dept. Agric. Tech. Bull. 666 (in press). 1938.

*Peronosporaceae*. Sporangia filamentous or with a sparingly inflated branching system, though not in intricate complexes; oogonia usually intercalary, smooth, subspherical,  $16-22\ \mu$  (aver.  $18.8\ \mu$ ) in diam. with cylindrical part at either pole  $4-5\ \mu$  up to delimiting septum; antheridia 2-5 on branches of a single hypha arising from the oogonial hypha at some distance; oospores completely filling oogonia  $14-20\ \mu$  (aver.  $17.3\ \mu$ ) in diam. Infrequently isolated from rotted rootlets and weakly pathogenic. Louisiana.

*Pythium spinosum* Sawada See *P. mamillatum* Meurs

**PYTHIUM SPLENDENS** Braun, Jour. Agric. Res. 30:1043-62. 1925. var. **HAWAIIENSIS** Sideris, Mycol. 24:38-9, figs. 4(D), 5(A), 12. 1932.

*Peronosporaceae*. The variety differs from the species in its stronger aerial mycelial development and larger conidia. Weak parasite on roots. Hawaii.

**PYTHIUM ULTIMUM** Trow, Ann. Bot. 15:269, pls. 15-16. 1901. Sacc., Syll. Fungorum 16:1123. 1902. Drechsler, Phytopath. 17:54-5. 1927. Rands and Dopp, U. S. Dept. Agric. Tech. Bull. 666 (in press). 1938.

*Peronosporaceae*. Conidia terminal and spherical, or intercalary and barrel-shaped; zoospores never formed; oogonia smooth, terminal or intercalary,  $19.6-22.9\ \mu$  (aver.  $20.6\ \mu$ ) in diam.; oospores not filling oogonia, spherical,  $14.7-18.3\ \mu$  (aver.  $16.3\ \mu$ ) in diam.; antheridia 1-2, pouch-like, arising in immediate proximity to oogonia. Frequent in rotting seed-piece roots and moderately pathogenic under unfavorable conditions. Louisiana.

**RAMULARIA** sp.

*Moniliaceae*. Unnamed species on leaves. Philippine Islands.

*Rheosporangium aphanidermatum* Edson See *Pythium aphanidermatum* (Edson) Fitzpatrick

**RHINOCLADIUM SACCHARI** Speg., Rev. Fac. Agron. y Vet. 2:250. 1896. Sacc., Syll. Fungorum 14:1073-4. 1899.

*Dematiaceae*. Mold powdery, sordid olivaceous; fertile hyphae erect, olivaceous, branched,  $100-150\ \mu$  tall; conidia acrogenous on tooth-like sterigmata, non-catenulate, obovate, 1-celled,  $6-8 \times 3\ \mu$ . On dead leaf-sheaths. Argentina.

**RHIZOCTONIA** spp.

*Mycelia sterilia*. Undetermined species associated with root rot, on cane trash, etc. Argentina, Australia, Barbados, Brazil, British Guiana, British W. Indies, Cuba, Dominican Republic, Hawaii, India, Java, Louisiana, Mauri-

tius, North Coast So. America, Peru, Philippine Islands, Puerto Rico, South-east United States, Uganda.

*Rhizoctonia bataticola* (Taub.) Butler See *Macrophomina phaseoli* (Maubl.) Ashby

RHIZOCTONIA DESTRUENS Tassi, Bull. Lab. Ort. Bot. Siena 3:50, pl. IV (figs. a-m). 1900. Sacc., Syll. Fungorum 16:1109. 1902.

*Mycelia sterilia*. Sclerotia subterranean, globose, white, then chestnut brown, white within, 2-5 mm diam. In roots. India. Duggar (Ann. Mo. Bot. Garden 2-451, 1915) suggests, "insufficient affinities with *Rhizoctonia* to be included, but critical study needed."

RHIZOCTONIA FERRUGINEA Matz, Jour. Dept. Agric. P. Rico 5(1):28-29, figs. 21-22. 1921.

*Mycelia sterilia*. Sclerotia white, finally rusty red, irregular. Isolated from diseased roots. Puerto Rico.

RHIZOCTONIA GRISEA (Stevenson) Matz, Jour. Dept. Agric. P. Rico 4(1):40. 1920. Matz, l. c. 5(1):22-24, figs. 13, 14. 1921. Sacc., Syll. Fungorum 25:1004. 1931. *Sclerotium griseum* Stevenson, Report Insular Exp. Sta. P. Rico 1917-18, p. 138. 1919.

*Mycelia sterilia*. Sclerotia light gray, subglobose to hemispheric or flattened, .5-2 mm diam. On dead and dying leaves and leaf-sheaths. Barbados, Dominican Republic, Puerto Rico. It has been suggested that the organism associated with the "banded sclerotial disease" or "Djamoer oepas" of the Orient should be referred here. See *Hypochnus sasakii* Shirai.

RHIZOCTONIA PALIDA Matz, Jour. Dept. Agric. P. Rico 5(1):28, figs. 18-20. 1921.

*Mycelia sterilia*. Sclerotia small, flat, yellow. Isolated from diseased roots. Puerto Rico.

*Rhizoctonia solani* Kuehn See *Corticium vagum* Berk. and Curt.

RHIZOPUS sp.

*Mucoraceae*. Unnamed species associated saprophytically with foot rot. Hawaii, Louisiana.

RHIZOPUS DELEMAR (Boidin) Wehm. and Hanzawa, Mycol. Centralbl. 1:86, 2 pls. 1912. Sacc., Syll. Fungorum 24:7. 1926.

*Mucoraceae*. In fermenting sugar. Japan.

ROSELLINIA sp.

*Sphaeriaceae*. Undetermined species associated with root disease. Madagascar.

ROSELLINIA PARAGUAYENSIS Speg., Anal. Mus. Nac. Buenos Aires (3) 12:338. 1909. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:214, pl. XXXI (figs. 16-18). 1917. *Anthostomella paraguayensis* Speg., Anal. Soc. Cient. Argentina 18:267. 1884. Sacc., Syll. Fungorum 9:510. 1891.

*Sphaeriaceae*. Perithecia black, gregarious, subglobose, 150-200  $\mu$ , glabrous, coriaceous, apapophysate; spores 5-13  $\times$  5-6  $\mu$ , fuliginous. On dead canes. Argentina, Brazil, Puerto Rico.

ROSELLINIA PULVERACEA (Ehrh.) Fekl., Symb. Mycol., p. 149. 1869. Sacc., Syll. Fungorum 1:264. 1882.

*Sphaeriaceae*. Perithecia superficial, globose, minutely tuberculate; spores fuscous,  $10-12 \times 7-9 \mu$ . On dead canes. Puerto Rico.

ROSTAFINSCKIA AUSTRALIS Speg., Anal. Soc. Cient. Argentina 10:151. 1880. Sacc., Syll. Fungorum 7:403. 1888. (As *Rostafinskyia*.) Spegazzini, Anal. Mus. Nac. Hist. Nat. Buenos Aires (3) 13:417. 1910.

*Myxomycetes*. Aethalium pulvinate-effuse; spores globose to ovoid, smooth, lilac colored,  $8-10 \times 5-6 \mu$ . Rotten stalks. Argentina. The species not recognized by Lister nor Macbride and Martin. Massee (Monograph) considered it a doubtful species.

*Saccharomyces apiculatus* Reess var. *sacchari* Racib. See *Hansenia apiculata* (Reess) Lindner var. *sacchari* Racib.

SACCHAROMYCES CONGLOMERATUS Reess, Bot. Unters. Über d. Alkoholgährungspilze, p. 82, pl. II (figs. 14-16). 1870. Sacc., Syll. Fungorum 8:917. 1889. Spegazzini, Rev. Fac. Agron. y Vet. 2:238. 1896.

*Saccharomycetaceae*. Vegetative cells  $5-6 \mu$  diam., subglobose; asci 2-4 spored. On dying leaves and culms and in molasses. Argentina. Guilliermond and Tanner (The Yeasts, p. 269, 1920) state, "the existence of this species is problematical."

SACCHAROMYCES MELLACEI Jörgensen, Microrg. Tread. Franc, p. 279, figs. 64, 65. 1899. Sacc., Syll. Fungorum 16:1153. 1902.

*Saccharomycetaceae*. Fermenting molasses. Jamaica. Guilliermond and Tanner (The Yeasts, p. 200, 1920) use the binomial *Schizosaccharomyces mellacei* Jörgensen.

SACCHAROMYCES MYCODERMA Reess, Bot. Unters. Über d. Alkoholgährungspilze, p. 83, pl. IV (figs. 10-11). 1870. Sacc., Syll. Fungorum 8:917. 1889. Spegazzini, l. c., p. 238. 1896.

*Saccharomycetaceae*. Cells ovate, elliptical or cylindrical,  $6-7 \times 2-4 \mu$ ; asci 4-spored. Dead and dying culms and in fermenting molasses. Argentina.

SACCHAROMYCES NOKKOENSIS Nakazawa, Ber. d. Inst. für Exper. Forschungen zu Taihoku Bd. III. 1914.

*Saccharomycetaceae*. Cells ellipsoidal,  $9.6-10.8 \times 3.6-5.25 \mu$ . In fermenting molasses. Formosa.

SACCHAROMYCES VORDERMANNII Went and Prin.-Geerligs, Arch. v.d. Java-Suikerind. 2:544-48, pl. III (figs. 10-13). 1894. Sacc., Syll. Fungorum 11:457. 1895.

*Saccharomycetaceae*. Asci globose-ellipsoid,  $8-10 \mu$  diam.; spores globose-ellipsoid,  $2 \times 4 \mu$ . Concerned in production of the alcoholic drink "arak" from molasses. Java.

SACCHAROMYCES ZOPFII Artari, Abh. d. Naturforsch. Ges. zu Halle 21:113, illus. 1897. Sacc., Syll. Fungorum 18:201. 1906. Guilliermond and Tanner, The Yeasts, p. 254, 1 fig. 1920.

*Saccharomycetaceae*. Cells ellipsoidal to spherical,  $3-6 \mu$ . Concerned in sugar deterioration. Cuba, Germany, Louisiana.

*Schizophyllum alneum* (L.) Schroet. See *Schizophyllum commune* Fr.

**SCHIZOPHYLLUM COMMUNE** Fr., Syst. Myc. 1:330. 1821. Sacc., Syll. Fungorum 5:655. 1887. Spegazzini, Rev. Fac. Agron. y Vet. 2:227. 1896. *Schizophyllum alneum* (L.) Schroet., Krypt. Fl. Schlesien 3(1):553. 1889. *Schizophyllum lobatum* Bref., Unters. Gesamentgeb. Mykol. 8:67. 1889. Sacc., Syll. Fungorum 14:123. 1899. (as *S. lobatum* Went). *Schizophyllum radiatum* (Swartz) Fr. ex Linder, Amer. Jour. Bot. 20:557-8, 3 pls. 1933.

*Agaricaceae*. Pileus thin, soft, coriaceous, sessile to short pseudo-stipitate, suborbicular to flabelliform, 1-4 cm broad; surface whitish villose to hirsute, white to umbrinous; gills radiating, bifid, edges revolute, gray; spores cylindrical, smooth, hyaline,  $6-7 \times 2-2.5 \mu$ . On dead and dying canes as a wound parasite. *Schizophyllum rot.*

Argentina, Brazil, British Guiana, British W. Indies, Cuba, Dominican Republic, Formosa, Haiti, Hawaii, India, Indo-China, Japan, Java, Martinique, Mexico, Philippine Islands, Puerto Rico, Trinidad, Union So. Africa, United States.

*Schizophyllum lobatum* Bref. See *Schizophyllum commune* Fr.

*Schizophyllum radiatum* (Swartz) Fr. See *Schizophyllum commune* Fr.

**SCHIZOSACCHAROMYCES FORMOSENSIS** Nakazawa, Ber. d. Inst. für Exp. Forschungen (Taihoku) Bd. III. 1914. Guilliermond and Tanner, The Yeasts, p. 203, 1 fig. 1920.

*Saccharomycetaceae*. Cells ellipsoidal to irregular,  $6-9 \times 7.2 \mu$ . In fermenting molasses. Formosa. Var. *akoensis* Nak. and var. *tapaniensis* Nak. also present, the former with cells larger than those of the species and the latter with intermediate cells.

**SCHIZOSACCHAROMYCES SAUTAWENSIS** Nakazawa, Ber. d. Inst. für Exp. Forschungen (Taihoku) Bd. III. 1914. Guilliermond and Tanner, The Yeasts, p. 204. 1920.

*Saccharomycetaceae*. Cells elliptical,  $7.2-8.4 \times 4.8 \mu$ . In fermenting molasses. Formosa.

**SCIRRHIA LOPHODERMIOIDES** E. and E., Bull. Torr. Bot. Club 22:435. 1895. Sacc., Syll. Fungorum 14:679. 1899.

*Dothideaceae*. Stromata elliptical or linear, .5-8 mm long, erumpent, black; spores cylindrical, greenish hyaline,  $35-40 \times 7-8 \mu$ . On dead cane. Puerto Rico.

**SCLEROSPORA** sp.

*Peronosporaceae*. Undetermined species on leaves. Formosa, India, Siam, Queensland. On *Saccharum spontaneum*, Philippine Islands, Siam.

**SCLEROSPORA GRABIELLOLA** (Sacc.) Schroet., Hedw. 18:86. 1879. Sacc., Syll. Fungorum 7:222. 1888.

*Peronosporaceae*. Transferred to *Saccharum* by inoculation. Melhus, et al, Iowa Agric. Exp. Sta. Bull. 111:304. 1928.

**SCLEROSPORA MISCANTHI** Miyake in Sacc., Syll. Fungorum 24:65. 1926. *Sclerospora matrospora* (?) Miyake, Sugar Exp. Sta. Formosa Bull. 1:58, tab. IX. 1911.

*Peronosporaceae*. This species, usually treated as specific on *Miscanthus*, is reported on *S. spontaneum* and *S. officinarum*. Oogonia spherical or irregu-

lar, 48-72  $\mu$ ; oospores spherical, 40-56  $\mu$  diam. (47-48.9  $\mu$  by Weston, Phytopath. 19:965. 1929). Philippine Islands.

SCLEROSPORA PHILIPPINENSIS Weston, Jour. Agric. Res. 19:118, col. pls. A, B; pls. 16-25. 1920. *S. indica* Butl., ex Uppal and Weston, Indian Jour. Agr. Sci. 6:715-9, pl. XLII. 1936.

*Peronosporaceae*. This species usually treated as specific to *Zea* and *Euchlaena* is reported on *Saccharum spontaneum* by Stevens. Philippine Islands.

SCLEROSPORA SACCHARI Miy., Sugar Exp. Sta. Formosa Bull. 1:12-13, 9 pls. 1911. (Translation Sugar 24:619. 1922.) Sacc., Syll. Fungorum 24:65. 1926.

*Peronosporaceae*. Conidiophores erect, arising from stomata, 160-170  $\mu$ ; conidia elliptical or oblong, produced nocturnally, evanescent, germinating by germ tube, 25-41  $\times$  15-23  $\mu$ ; oospores in host tissues, yellow, globular, thick-walled, 40-50  $\mu$ ; oogonium chestnut-brown, irregularly elliptical, 49-58  $\times$  55-73  $\mu$ . Producing yellow stripes on leaves which split along the stripes giving a characteristic shredded appearance. Young diseased canes produce aerial broom-like growths. *Downy mildew, leaf stripe, leaf-splitting disease*.

Fiji, Formosa, India, Japan, New Guinea, Philippine Islands, Queensland, Siam.

SCLEROSPORA SPONTANEA Weston, Jour. Agric. Res. 20:678, 4 pls. 1921. Sacc., Syll. Fungorum 24:167. 1926.

*Peronosporaceae*. Conidiophores 350-550  $\mu$  long; sterigmata 13  $\mu$ ; conidia hyaline, ellipsoid to cylindrical, 39-45  $\times$  15-17  $\mu$ . Downy mildew of leaves of *Saccharum officinarum* and *S. spontaneum*. Philippine Islands, Siam.

SCLEROTIUM sp.

*Mycelia sterilia*. Mycelium binds upper leafsheaths, choking and killing growing point and stem, followed by secondary rot; sclerotia superficial, pink. India, Philippine Islands, Queensland. *Spindle-top*.

*Sclerotium* sp. See *Hypochnus sasakii* Shirai

*Sclerotium bataticola* Taub. See *Macrophomina phaseoli* (Maubl.) Ashby

*Sclerotium griseum* Stevenson See *Rhizoctonia grisea* (Stevenson) Matz

SCLEROTIUM ROLFSII Sacc., Ann. Myc. 9:257. 1911. Sacc., Syll. Fungorum 22:1500. 1913. Wakker and Went, Ziekten Suikerriet op Java, pp. 121-8, col. pl. XIV (figs. 2-3). 1898. Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:201-2, pl. XXV (fig. 3). 1917.

*Mycelia sterilia*. Mycelium white, feathery, growing up along leaf sheaths, binding them together and causing a characteristic red rot; sclerotia superficial, spherical, white through yellow-brown to deep red-brown, .5-.8 mm diam., "mustard-seed-like." *Red rot of the leaf-sheath*.

Antigua, Argentina, Australia, Barbados, Brazil, British Guiana, British W. Indies, Cuba, Dominican Republic, Fiji, Formosa, Hawaii, India, Indo-China, Jamaica, Java, North Coast So. America, Philippine Islands, Puerto Rico, Southern United States, St. Croix, Trinidad. Japanese workers have reported *Corticium* (*Hypochnus*) *centrifugum* (q.v.) as the perfect stage. Curzi (Bol. R. Staz. Pat. Veg. n.s. 11:306, 9 pls., 1931), however, sets up the binomial *Corticium rolfsii* n.n., stating that *C. centrifugum* cannot be considered

the perfect stage of the true *S. rolfsii*. See also Mundkur, Indian Jour. Agr. Sci. 4:779-81, 1 pl. 1934.

**SCOPULARIA** sp.

*Dematiaceae*. An abundant gray mold on germinating cane. Saprophytic. Louisiana.

**SCYTINOTUS DISTANTIFOLIUS** Murr., No. Amer. Flora 9:239. 1915. Sacc., Syll. Fungorum 23:175. 1925.

*Agaricaceae*. Pilei resupinate, becoming sessile, imbricate, 5-10 mm across; surface smooth, white, pruinose to glabrous; context thin, white; gills very distant, irregular, yellowish. On dead leaves. Puerto Rico.

**SEPTONEMA SACCHARI** Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:225. 1917. Sacc., Syll. Fungorum 25:811. 1931.

*Dematiaceae*. Small black patches on substrata; conidia catenulate, 1-3 septate, basal cell truncate, brown, minutely spiny,  $13-25 \times 7.25 \mu$ . On dead leaves. Puerto Rico.

**SEPTORIELLA PHILIPPINENSIS** Sacc., Nuovo Giorn. Bot. Ital. 23:211. 1916. Sacc., Syll. Fungorum 25:480. 1931.

*Phomaceae*. Stromata innate-erumpent, black, 2 mm long; conidia bacillar, often curved, 5-6 septate,  $60-65 \times 3.5-3.7 \mu$ . On dying leaves of *Saccharum spontaneum*. Philippine Islands.

**SPEGAZZINIA ORNATA** Sacc., Michelia 2:172. 1882. Sacc., Syll. Fungorum 4:758. 1886. Bessey, Jour. Mycology 13:43-45, 1 pl. 1907.

*Tuberculariaceae*. Sporodochia superficial, hemispherical, compact, black; conidia sarcinaeform, 4-celled, heavily constricted at the septae, fuliginous, strongly tuberculate,  $16-20 \mu$  diam.; conidiophores  $30-40 \mu$  long. On dead leaves. Puerto Rico. On *Saccharum ciliare*. Java. Bessey (l.c.) suggests that *S. tessarthra* is synonymous.

**SPEGAZZINIA TESSARTHRA** (Berk. and Curt.) Sacc., Syll. Fungorum 4:758. 1886.

*Tuberculariaceae*. Sporodochia olivaceous, variable; cells of conidia smooth, then echinulate,  $25 \mu$  diam. On dead leaves. Alabama.

**SPEGAZZINIA TUCUMANENSIS** Speg., Rev. Fac. Agron. y Vet. 2:256. 1896. Sacc., Syll. Fungorum 14:1132. 1899.

*Tuberculariaceae*. Sporodochia superficial, black, hemispherical, .5-1.5 mm diam.; conidia sarciniform, 4-celled, with many sterigmata or protuberances on which microconidia are borne, black,  $14-16 \times 7-10 \mu$ . Spegazzini says his species differs from *S. ornata*, but may be *S. tessarthra*. On rotten cane trash. Argentina.

**SPHAERELLA SACCHARI** Speg., Rev. Fac. Agron. y Vet. 2:230. 1896. Sacc., Syll. Fungorum 14:533. 1899.

*Sphaeriaceae*. Spots none or indefinite; perithecia hypophyllous, crowded, immersed,  $130-180 \mu$  diam., paraphysate; spores ellipsoid, 1-septate, hyaline,  $16-20 \times 5-6 \mu$ . On dead leaves. Argentina, Cuba, Puerto Rico, Venezuela.

*Sphaerella sacchari* Wakker See *Sphaerella wakkeri* Sacc. and Syd.

**SPHAERELLA SACCHAROIDES** Peck, New York State Mus. Bull. 167:48. 1913. Sacc., Syll. Fungorum 24:867. 1928.



*Sphaeriaceae*. Spots definite, oblong, .5-1 cm long, white, brownish on margin; perithecia black, epiphyllous; spores oblong or subfusiform, hyaline, 1-septate,  $25-30 \times 5-6 \mu$ . Differs from Spegazzini's species in causing definite whitish spots, and in having longer asci and spores. On leaves. Cuba.

*SPHAERELLA STRIATIFORMANS* (Cobb) Delacroix, Mal. Plant. Cult. de les Pays Chauds, p. 568, pl. LXIX (fig. 1). 1911. *Sphaerella striatiformans* (Cobb) Sacc. and Trott. in Sacc., Syll. Fungorum 24:867. 1928. *Mycosphaerella striatiformans* Cobb, Hawaii. Sugar Planters' Assoc. Exp. Sta. Bull. (Path. and Phys. Ser.) 5:208, fig. 48. 1906.

*Sphaeriaceae*. Perithecia hypophyllous, dark, subglobose,  $140 \mu$  diam.; spores nearly hyaline, 2-celled, slightly constricted at septa,  $15-16 \times 5.5-6 \mu$ . Associated with shredding of leaves. Fiji, Hawaii, Java.

*Leaf-splitting disease.*

*SPHAERELLA WAKKERI* Sacc. and Syd. in Sacc., Syll. Fungorum 14:533. 1899. *Sphaerella sacchari* Wakker in Wakker and Went, Ziekten Suikerriet op Java, p. 196. 1899.

*Sphaeriaceae*. Perithecia immersed, dark-fuscos,  $64 \mu$  diam.; spores hyaline, fusoid, acute at both ends, 1-septate,  $16 \times 4 \mu$ . On dead leaves. Java.

*Sphaeria gelatinosa* Tode See *Chromocrea gelatinosa* (Tode) Seaver

*SPHAEROBOLUS STELLATUS* Tode, Fung. Meckl. 1:43. 1790. Sacc., Syll. Fungorum 7:46. 1888. Coker and Couch, Gastromycetes East. U. S. and Canada, p. 147, pls. 82, 117. 1928.

*Nidulariaceae* (*Sphaerobolaceae*). Plants 1.5-2 mm diam., dull ochraceous to white, spherical, then opening by 4-7 stellate lobes, ejecting central spore-balls which are smooth, dark-chestnut brown; spores smooth, oblong,  $7.4-10 \times 3.7-4.8 \mu$ . On cane trash. Puerto Rico.

*Sphaeronema adiposum* Butler See *Ceratostomella adiposum* (Butler) Sartoris

*SPHAEROPSIS PSEUDO-DIPLODIA* (Fckl.) Delacr., Bull. Soc. Myc. France 19:350-2. 1903. *Diplodia pseudo-diplodia* Fckl., Symb. Mycol., p. 393. 1869-70. Sacc., Syll. Fungorum 3:341. 1884.

*Phomaceae*. Conidia oblong-ovate, fuscous, non-septate,  $25 \times 12 \mu$ . "Parasitic at tip of culm." Brazil. Not clear what fungus Avena-Sacca had (Bol. Agric. São Paulo 17:638-40, 2 figs., 1917). Delacroix considers the fungus identical with *Sphaeropsis malorum* Pk.

*Sphaeropsis sacchari* Cke. See *Macrophoma sacchari* (Cke.) Berl. and Vogl.

*SPHAERULINA SACCHARI* P. Henn., Hedwigia 44:62. 1905. Sacc., Syll. Fungorum 17:694. 1905.

*Sphaeriaceae*. Spots round, oblong or confluent, pale, red-brown borders; perithecia hypophyllous, immersed, then erumpent,  $80-100 \mu$  diam.; spores oblong, fusoid or clavate, 3-septate, constricted at septa,  $15-20 \times 3.5-4 \mu$ . On leaves. Costa Rica, Peru, Philippine Islands.

*Sporochisma paradoxum* de Seynes See *Ceratostomella paradoxa* (de Seynes) Dade

*SPOROBYE SACCHARI* Speg., Rev. Fac. Agron. y Vet. 2:253. 1896. Sacc., Syll. Fungorum 14:1110. 1899.

*Stilbaceae*. Conidial masses 40-80  $\mu$  diam.; conidia 1-celled, dark, smooth, ovate or elliptical, 6-10  $\times$  3-5  $\mu$ . On rotten trash. Argentina.

SPORODESMIUM SACCHARI Speg., Anal. Mus. Nac. Buenos Aires (3)13:443, 1 fig. 1910. Sacc., Syll. Fungorum 22:1404. 1913.

*Dematiaceae*. Acervuli linear, compact, black, 3-15 mm long; conidia ovate to pyriform, muriform, scarcely constricted at septa, 16-22  $\times$  10-12  $\mu$ . On rotten culms. Argentina.

STACHYBOTRYS PULCRA Speg., Rev. Fac. Agron. y Vet. 2:248. 1896. Sacc., Syll. Fungorum 14:1071. 1899.

*Dematiaceae*. Fertile hyphae erect, 100-200  $\mu$  high, fuliginous; conidia acrogenous, ellipsoid, 10-15  $\times$  5-6  $\mu$ . On dead and dying leaves and culms. Argentina.

STAURONEMA SACCHARI Syd. and Butl., Ann. Myc. 14:217. 1916. Sacc., Syll. Fungorum 25:530. 1931.

*Exicipulaceae*. Pycnidia aggregated, sessile, superficial, concave, black, .3-.6 mm diam.; setae numerous, rigid, black, with obtuse apices, 70-350  $\times$  6-9  $\mu$ ; conidia cylindrical, curved, 1-celled, hyaline, 10-12  $\times$  3  $\mu$ . On rotten culms. India.

STEMONITIS FUSCA Roth., Roem. Mag. Bot. 2:26. 1787. Macbride and Martin, The Myxomycetes, p. 162, pl. XI (figs. 249-60). 1934.

*Stemonitaceae*. Sporangia cylindrical, in tufts, fuscous, 6-8 mm high; stems black, shining; spores fuscous in mass, pale violet, with blunt spines or warts, 10  $\times$  7.5  $\mu$ . On cane trash. Puerto Rico.

STEMONITIS HERBATICA Pk., New York State Mus. Report 26:75. 1874. Macbride and Martin, The Myxomycetes, p. 170, pl. XII (figs. 276-7). 1934.

*Stemonitaceae*. Sporangia in scattered tufts, cylindrical, stipitate or nearly sessile, natal-brown, 3-7 mm tall; stipes black; spores pale brown, minutely warted, 7-9  $\mu$ . On cane trash. British Guiana.

STEMONITIS SPLENDENS Rost., Monogr., p. 195. 1875. Macbride and Martin, The Myxomycetes, p. 166, pl. XI (figs. 262-3). 1934.

*Stemonitaceae*. Sporangia long, cylindrical, flexuous, natal-brown, 14-23 mm tall; stems black, polished; spores verrucose, lilaceous brown, 8  $\mu$  diam. On cane trash. Puerto Rico.

*Sterigmatocystis flavipes* Bainier and Sartory See *Aspergillus flavipes* (Bainier and Sartory) Thom and Church

*Sterigmatocystis niger* v. Tiegh. See *Aspergillus niger* v. Tiegh.

*Sterigmatocystis sydowi* Bainier and Sartory See *Aspergillus sydowi* (Bainier and Sartory) Thom and Church

STIGMELLA SACCHARI Speg., Rev. Fac. Agron. y Vet. 2:251. 1896. Sacc., Syll. Fungorum 14:1091. 1899.

*Dematiaceae*. Acervuli orbicular to pulvinate, dark, 100-150  $\mu$  diam.; conidia ellipsoid or ovate, muricate, fuliginous, 20-30  $\times$  10-15  $\mu$ . On dead and dying leaves. Argentina.

STIGMINA PULCHELLA Speg., Rev. Fac. Agron. y Vet. 2:251. 1896. Sacc., Syll. Fungorum 14:1084. 1899.

*Dematiaceae*. Acervuli small, black, irregular; conidia fusiform, 3-4 septate, constricted at septa,  $20-24 \times 6-8 \mu$ . On dead leaves. Argentina.

STIGMINA SACCHARI Speg., Rev. Fac. Agron y Vet. 2:251. 1896. Sacc., Syll. Fungorum 14:1083. 1899.

*Dematiaceae*. Acervuli black, 60-100  $\mu$  diam.; conidia fusiform or subclavate, obtuse at both ends, 2-septate, constricted at septa, fuliginous-olivaceous,  $18-25 \times 5-7 \mu$ . On dead and dying leaves. Argentina.

STILBUM sp.

*Stilbaceae*. On dead canes. Puerto Rico.

STILBUM INCARNATUM Wakker in Wakker and Went, Ziekten Suikerriet op Java, p. 197. 1898. Sacc., Syll. Fungorum 14:1108. 1899.

*Stilbaceae*. Stipes incarnate, 2 mm long; conidia hyaline, oval, in mucous-heads, pink,  $12 \times 6 \mu$ . On rotten canes. Java.

STILBUM PROLIFERUM Marchal, Bull. Soc. Belge Microsc. 20:267, pl. VIII (fig. 3). 1894. Sacc., Syll. Fungorum 11:640. 1895.

*Stilbaceae*. Coremia 600-800  $\times$  35-60  $\mu$ ; heads globose, bright red, 120-150  $\mu$  diam.; conidia ellipsoid, hyaline,  $5-7 \times 2.5-3.5 \mu$ . On rotten culms. Belgian Congo.

*Strumella sacchari* Cke. See *Melanconium sacchari* Mass.

SYNCEPHALASTRUM sp.

*Mucoraceae*. An undetermined species in deteriorating sugar. Louisiana.

TAPESIA sp.

*Mollisiaceae*. An undetermined species on dead canes. Puerto Rico.

TETRACOCOSSIPORIS SACCHARI Stevenson, Jour. Dept. Agric. P. Rico 1:225, pl. XXVII (figs. 19, 20). 1917. Sacc., Syll. Fungorum 25:863. 1931. (As *Tetracoccosporium*.)

*Dematiaceae*. Fungus masses sooty, black, subcircular to irregular, 1-2 mm diam.; fertile hyphae erect, hyaline to smoky; septa as broad black bands; conidia pleurogenous, sessile, covering conidiophores in regular series, rugulose, cruciately divided into 4 cells, 10  $\mu$  diam. Dead leaves. Puerto Rico.

TETRAPLOA ARISTATA Berk. and Br., Ann. Nat. Hist. (2)5:460, pl. IX (fig. 6). 1850. Sacc., Syll. Fungorum 4:516. 1886.

*Dematiaceae*. Fungus masses dark olivaceous; conidia oblong, muriform, ochraceous-fuliginous,  $30 \times 22 \mu$ ; beaks concolorous, 3-4 septate,  $60-90 \times 4 \mu$ . On dead leaves and stalks. Alabama, Barbados, Cuba, Dominican Republic, Puerto Rico.

*Thelephora dendritica* Pers. See *Cladoderris dendritica* (Pers.) Berk.

*Thielaviopsis ethacetica* Went See *Ceratostomella paradoxa* (deSeynes) Dade

*Thielaviopsis paradoxa* (deSeynes) v. Hoeh. See *Ceratostomella paradoxa* (de Seynes) Dade

*Thyridaria tarda* Bancroft See *Physalospora rhodina* (Berk. and Curt.) Cke.

TORULA COMMUNIS Browne, Jour. Ind. Eng. Chem. 10:178-90. 1918.

*Dematiaceae*. Cells yeast-like, black. In Cuban raw sugar examined in New York.

TORULA DICHROA Sacc., Nuovo Giorn. Bot. Ital. 23:213. 1916. Sacc., Syll. Fungorum 25:760. 1931.

*Dematiaceae*. Mycelium effuse, olivaceous; conidia globose, smooth, catenulate, fuliginous, 7.5-8.5  $\mu$  diam. On dead culms of *Saccharum spontaneum*. Philippine Islands.

TRAMETES NIVOSA (Berk.) Murr., No. Amer. Fl. 9:42. 1907. *Polyporus nivosus* Berk., Jour. Bot. and Kew Misc. 8:196. 1856. Sacc., Syll. Fungorum 6:140. 1888.

*Polyporaceae*. On dead canes. Dominican Republic, Puerto Rico. Specimens referred here are probably not true *Tr. nivosa*.

TRAMETES PUSILLA Racib., Arch. v. de Java-Suikerind. 6:489-90. 1890.

*Polyporaceae*. Fruiting bodies arising at leaf-scar, leathery, semi-circular, 2 cm wide  $\times$  1 cm high, covered with glistening hairs 2 mm long, zonate above, light yellow alternating with dark brown; pores round to 5-6 angular near base of fruit. Causing large, dry cavities (lined with thick, white mycelial layer) in internodes of standing cane, resulting in breakage and death of top. Java. No further references to this species found.

TRELEASIA SACCHARI Speg., Rev. Fac. Agron. y Vet. 2:235. 1896. Sacc., Syll. Fungorum 14:640-41. 1899.

*Hypocreaceae*. Stromata superficial, white, cottony; perithecia imbedded, long beaked; spores linear-fusiform, acute, 1-septate, smooth, hyaline, 50-60  $\times$  7-8  $\mu$ . On decaying leaves. Argentina.

TRELEASIELLA SACCHARI Speg., Rev. Fac. Agron. y Vet. 2:242. 1896. Sacc., Syll. Fungorum 14:989. 1899.

*Zythiaceae*. Acervuli 1-3 mm diam., red; pycnidia immersed; conidia cylindrical, 1-celled, hyaline, 7-10  $\times$  4-5  $\mu$ . On dead cane. The imperfect stage of *Treleasia sacchari* Speg. Argentina.

TREMELLODENDRON SIMPLEX Burt., Ann. Mo. Bot. Garden 2:742-3, pl. 26 (fig. 5). 1915. Sacc., Syll. Fungorum 23:575. 1925.

*Tremellaceae*. Fructifications 2 cm long, 2 mm thick, erect or suberect, brittle, wrinkled, black above, olive-ocher toward the base; spores hyaline, smooth, 7.5-9  $\times$  5-6  $\mu$ . On dead cane. Puerto Rico.

TRICHODERMA sp.

*Moniliaceae*. Unnamed species as a saprophyte in diseased roots, and in deteriorating sugar. Louisiana.

TRICHODERMA KONINGI Oud., Arch. Neerl. Sci. Nat. ser. 2, 7:291, pl. 31 (figs. 1-7). 1902. Sacc., Syll. Fungorum 18:512. 1906.

*Moniliaceae*. Colonies floccose; conidiophores up to 25  $\mu$  long; fruiting heads up to 10  $\mu$  diam.; conidia oblong to elliptical, smooth, hyaline, 3.2-4.8  $\times$  1.8-3  $\mu$ . Associated with diseased roots. Peru. Often confused with the following species.

TRICHODERMA LIGNORUM (Tode) Harz, Bull. Soc. Imper. Nat. Moscou 44:116, pl. 4 (fig. 6). 1871. Sacc., Syll. Fungorum 4:59. 1886. Spegazzini, Rev. Fac. Agron. y Vet. 2:244. 1896.

*Moniliaceae*. Colonies tufted, conidiophores up to  $60\ \mu$  long; conidial heads  $6.5\text{--}10\ \mu$  diam.; conidia smooth, hyaline, ovoid,  $3.8\text{--}5 \times 2.5\text{--}3\ \mu$ . On dead and dying stalks and leaves, and associated with death of cuttings. Barbados, British Guiana, Hawaii, Java, Louisiana, Puerto Rico, Virgin Islands.

*Trichosphaeria sacchari* Mass. See *Melanconium sacchari* Mass.

TRIPOSPORIUM MURICATUM Wakker in Wakker and Went, Ziekten Suikerriet op Java, p. 197. 1898. Sacc., Syll. Fungorum 14:1107. 1899.

*Dematiaceae*. Conidia solitary, fuscous, spherical, 3-radiate, each section muricate. On dead leaves. Java.

TROGIA sp.

*Agaricaceae*. An unnamed species on dead canes. Puerto Rico.

*Trullula sacchari* Ell. and Everh. See *Melanconium sacchari* Mass.

TUBERCULARIA SACCHARICOLA Speg., Rev. Fac. Agron. y Vet. 2:254. 1896. Sacc., Syll. Fungorum 14:1115. 1899.

*Tuberculariaceae*. Sporodochia pulvinate, white to pink, .3-.5 mm diam.; conidia ovate or elliptical, ends obtuse, smooth. On dead canes. Argentina, Dominican Republic, Puerto Rico.

*Uredo kuehnii* (Krueger) Wakker and Went See *Puccinia kuehnii* (Krueger) Butler

*Uromyces kuehnii* Krueger See *Puccinia kuehnii* (Krueger) Butler

*Uromyces sacchari* Krueger in Racib. Fungi Jav. No. 26. In error for *Uromyces kuehnii* Krueger See *Puccinia kuehnii* (Krueger) Butler

USTILAGINOIDEA SACCHARI-NARENGAE K. Saw., Taiwan Hakubutsu Gakkwai Kwaihô (Jour. Formosan Nat. Hist. Soc.) 4 (15) : 4-5, pl. 3. 1914. Tanaka, Mycologia 14:87. 1922. Sacc., Syll. Fungorum 23:632. 1925.

*Dematiaceae*. Stromata in ovaries, dark brown, top shaped, at first covered by membrane, then rupturing to expose dark olive spore masses; conidia globose or ovoid, warted, dark olive,  $4\text{--}5.5\ \mu$ . Parasitic in ovaries of *Saccharum narenga*. Formosa.

USTILAGO CONSIMILIS Syd., Ann. Myc. 22:281. 1924.

*Ustilaginaceae*. Differs from *U. scitaminea* Syd. in spore size,  $5\text{--}7\ \mu$  (aver. 6). Sori deforming inflorescences of *Saccharum fuscum*. India. Earlier reports from India of *U. sacchari* on this host presumably refer to this species. Zundel (Mycologia 22:27-8, 1930) refers here all smuts reported on *Saccharum* spp.

USTILAGO COURTOISI Ciferri, Ann. Myc. 29:71. 1931.

*Ustilaginaceae*. Ovaries hypertrophied; spore mass black, 2-3 mm long; spores yellow-brown to brown, more or less spherical or subpolyhedral,  $8\text{--}12\ \mu$  diam.; epispore smooth,  $1\text{--}1.5\ \mu$  thick. In florets of *Saccharum* sp. China.

USTILAGO SACCHARI Rabh., Sitzungsber. Naturwiss. Ges. Isis 4:227. 1870. Sacc., Syll. Fungorum 7:456. 1888. Wakker and Went, Ziekten Suikerriet op Java, pp. 24-36, pl. II. 1898. Dastur, Ann. Bot. 34:391-7, 10 figs. 1920.

*Ustilaginaceae*. Sydow, Ciferri, and others have pointed out that the type specimen is on *Erianthus* (*Saccharum*) *ravennae* and is distinct from the smut on true *Saccharum* species. Hence a new name for the latter was proposed. See *U. scitaminea*.

USTILAGO SACCHARI-CILIARIS Bref., Unters. Mykologie 12:109, pl. VI (fig. 26). 1895. Sacc., Syll. Fungorum 14:418. 1899.

*Ustilaginaceae*. Spores globose, 9-11  $\mu$  diam. (7-11  $\mu$  per Ciferri). In ovaries of *Saccharum ciliare* (*S. sara*). India.

USTILAGO SCITAMINEA Syd., Ann. Myc. 22:281. 1924. Ciferri, Ann. Myc. 29:71. 1931.

*Ustilaginaceae*. Sori transforming the floral stem into a long curved, leafless, stemlike outgrowth covered by a thin covering of host tissue, the lower part concealed by the sheath; spores reddish brown, globose to subglobose, finely punctulate, 5.5-7.5  $\mu$ . (6-10  $\mu$  per Ciferri, l. c.). Attacking living plants of *Saccharum officinarum*. Smut.

Belgian Congo, Brazil (?), British Guiana (?), Egypt, Formosa, India, Indo-China, Java, Madagascar, Mauritius, Philippine Islands, Portugal, Portuguese E. Africa, Queensland, Reunion, South China, Union So. Africa. *S. arundinaceum*, China; *S. barberi*, Mauritius; *S. spontaneum*, Java, Philippine Islands, Turkestan. The report of Ustilago on *Saccharum* in New Mexico is an error, *Holcus* being the host involved. Italian reports of *U. sacchari* relate to the fungus on *Erianthus*. Sydow (l.c.) mentions, but does not name, the form on *Saccharum spontaneum*, which is intermediate in spore size (5-6  $\mu$ ).

VALSA SACCHARI Stevenson (In ed.), Jour. Dept. Agric. P. Rico 2:157. 1918.

*Sphaeriaceae*. On dead stalks. Puerto Rico.

VALSARIA SUBTROPICA Speg., Anal. Mus. Nac. Buenos Aires (3)10:372. 1909. Sacc., Syll. Fungorum 22:393. 1913. Aversa-Sacca, Bol. Agric. São Paulo 17:613-14, 1 fig. 1916.

*Sphaeriaceae*. Perithecia innate-erumpent, scattered or aggregated in stromata, black, subglobose, 150-200  $\mu$ ; spores 2-celled, elongate-ellipsoid, slightly constricted at septa, fuliginous, 14-16  $\times$  5-6  $\mu$ . On rotting culms. Argentina, Brazil, Puerto Rico.

*Venturia sacchari* v. Breda de Haan See *Eriosphaeria sacchari* (v. Breda de Haan) Went

VENTURIA STERILIS Speg., Rév. Fac. Agron. y Vet. 2:230. 1896. Sacc., Syll. Fungorum 14:542. 1899.

*Sphaeriaceae*. Perithecia superficial on lower leaf surfaces and along mid-ribs; asci and spores "non visae." Doubtful species. On dead and dying leaves. Argentina.

VERMICULARIA GRAMINICOLA Westend., Bull. Acad. Roy. Belg. II, 2:566. 1857. Sacc., Syll. Fungorum 3:235. 1884. Spegazzini, Rev. Fac. Agron. y Vet. 2:235. 1884.

*Melanconiaceae*. Sporodochia 120-150  $\mu$  diam.; setae erect, black, 100-200  $\times$  5-6  $\mu$ ; conidia hyaline, fusiform, straight or slightly curved, attenuate at

both ends, 2-4 guttulate,  $30 \times 5 \mu$  ( $22-30 \times 5-6 \mu$  per Spegazzini). On dead and dying leaves. Argentina, Puerto Rico.

VERMICULARIA SACCHARI Averna-Sacca, Bol. Agric. São Paulo 17:629, 2 figs. 1916. Sacc., Syll. Fungorum 25:193-4. 1931.

*Melanconiaceae*. Sporodochia globose, 165-275  $\mu$  high, 330-500  $\mu$  wide, on olivaceous or brown spots; setae copious, up to 1 mm long, acute; conidia cylindrical to curved, continuous, hyaline,  $10-13 \times 2-3 \mu$ , ciliate at both ends (hence as Saccardo points out does not belong in *Vermicularia*). On culms and leaves. Brazil.

VERTICICLADIUM GRAMINICOLUM Johnston and Stevenson, Jour. Dept. Agric. P. Rico 1:226, pl. XXIX (figs. 14, 15). 1917. Sacc., Syll. Fungorum 25:784. 1931.

*Dematiaceae*. Effuse, forming a dull brown to gray fungus layer; fertile hyphae erect, verticillately branched, 3-4 branches at each node; branches cylindrical; conidia elliptical to cylindrical, hyaline,  $6.8-11 \times 3-4 \mu$ . On dead leaves. Puerto Rico.

VERTICILLIUM sp.

*Moniliaceae*. Unnamed species associated with root rot, top rot, on trash, etc. Hawaii, India, Uganda.

VERTICILLIUM GLAUCUM Bon., Handb. Allg. Mykol., p. 97, fig. 120. 1851. Sacc., Syll. Fungorum 4:157. 1888.

*Moniliaceae*. Forming round, blue-green superficial masses; conidia globose, smooth, subhyaline, 2.5  $\mu$  diam. On dead leaves. Java.

*Verticillium sacchari* Went See *Hypocrea sacchari* Went

VOLUTINA sp.

*Tuberculariaceae*. An unnamed species on dead canes. Puerto Rico.

XIPHOMYCES SACCHARI Syd., Ann. Myc. 14:374. 1916. Sacc., Syll. Fungorum 25:990. 1931. (As *Xyphomyces*.)

*Tuberculariaceae*. Sporodochia .5-1 mm diam., black, often confluent; conidia elongate-cylindrical, yellow-green, continuous,  $75-110 \times 12-15 \mu$ . On dead leaf sheaths. Philippine Islands.

XYLARIA APICULATA Cke., Grevillea 8:66. 1879. Sacc., Syll. Fungorum 1:334. 1882.

*Sphaeriaceae*. Fruiting bodies black, stipitate, erect, surmounted by spine-like apiculi, up to 4 cm tall, cylindrical; perithecia immersed, papillate; spores lanceolate, slightly curved, dark brown,  $20-22 \times 7 \mu$ . On dead canes. Puerto Rico.

ZYGODESMUS GUARAPIENSE Speg., Anal. Soc. Cien. Argentina 22:209. 1886. Sacc., Syll. Fungorum 10:582. 1892.

*Dematiaceae*. Acervuli superficial, black,  $2-5 \times 1-1.5$  mm; conidia globose or angular by compression, smooth, olivaceous,  $5-9 \times 3-5 \mu$ . On rotten trash. Brazil.

## Sugar Prices

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96° CENTRIFUGALS FOR THE PERIOD  
JUNE 20, 1938, TO SEPTEMBER 14, 1938

Date	Per Pound	Per Ton	Remarks
June 20, 1938.....	2.66¢	\$53.20	Philippines.
" 28.....	2.68	53.60	Philippines.
July 5.....	2.71	54.20	Puerto Ricos.
" 7.....	2.72	54.40	Puerto Ricos; Cubas.
" 11.....	2.75	55.00	Puerto Ricos; Philippines.
" 13.....	2.80	57.60	Puerto Ricos.
" 14.....	2.85	57.00	Philippines; Cubas.
" 20.....	2.82	56.40	Cubas.
" 27.....	2.80	56.00	Cubas.
" 28.....	2.78	55.60	Cubas.
Aug. 1.....	2.75	55.00	Philippines.
" 22.....	2.80	56.00	Puerto Ricos.
" 26.....	2.90	58.00	Puerto Ricos.
" 30.....	2.915	58.30	Philippines, 2.90; Cubas, 2.93.
" 31.....	2.95	59.00	Puerto Ricos.
Sept. 8.....	2.91	58.20	Philippines, 2.92; Puerto Ricos, 2.90.
" 9.....	2.90	58.00	Cubas.
" 13.....	2.92	58.40	
" 14.....	3.00	60.00	

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